Hydraulic and pollutant treatment performance of sand based biofilters

Conductivité hydraulique et rendement épuratoire de filtres de biorétention à base de sable

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RÉSUMÉ
Il a été démontré que les biofiltres (systèmes de biofiltration, autrement dits de biorétention) représentent une option efficace pour le traitement des rejets urbains de temps de pluie. Le but de cette étude était de tester un filtre alternatif à base de sable, dont la spécification technique et la construction à partir de matériaux inertes serait facile et fiable, et qui (i) soutiendrait la croissance végétale, (ii) maintiendrait la conductivité hydraulique et (iii) serait efficace quant au traitement des rejets urbains de temps de pluie.

Cette expérience comportait vingt colonnes de biorétention, dans lesquelles deux sables fins de conductivité hydraulique initiale différente étaient testés en configuration plantée et non-plantée. Les résultats ont démontré que les plantes poussaient bien dans les deux types de sable et qu’après un an (c’est-à-dire lors du dernier événement de prélèvement), le niveau de traitement des colonnes plantées était comparable à celui d’autres biofiltres végétalisés à base d’un sable limoneux (qui est typique pour les ouvrages de biorétention actuels). Cependant, la conductivité hydraulique des filtres de biorétention s’était considérablement détériorée, en particulier dans le cas des filtres plantés.

En conclusion, cette étude a démontré que les systèmes de biorétention à base de sable, construits selon les spécifications décrites dans cette publication, représentent une option valable pour le traitement des rejets urbains de temps de pluie. Les principaux avantages de ce filtre sont liés à la reproductibilité du matériau et à la variabilité réduite des résultats.

ABSTRACT
Biofilters (also called biofiltration or bioretention systems) have been proven to be an effective option for the treatment of pollutants in urban stormwater. The aim of this study was to independently test an alternative sand based filter media, which could be reliably and easily specified and constructed from inert material, and which would (i) sustain adequate plant growth, (ii) maintain hydraulic conductivity, and (iii) achieve effective pollutant removal.

Twenty biofilter columns were constructed for this experiment, using two fine sands of different initial drainage rates, tested in vegetated and non-vegetated configurations. The results showed that, independently of the type of sand used, plant growth was sustained in all biofilters, and that after one year (i.e. at the time of the last sampling event), the pollutant treatment performance of vegetated columns was comparable to loamy sand based biofilters, which are typically used in current practice. However, the results also showed that after one year of exposure to stormwater, the hydraulic conductivity of the filters had greatly deteriorated, in particular for the vegetated configurations.

The results of this study demonstrated that sand based biofilters, built according to these simple filter media specifications, could be used as a viable option for stormwater treatment. The main advantages of this alternative specification are its reproducibility and reduced variability.

KEYWORDS
Hydraulic conductivity, nutrient treatment performance, plant growth, sand based biofilter, stormwater
1 INTRODUCTION

Biofiltration systems (also known as raingardens, biofilters and bioretention systems) are widely used in the framework of Water Sensitive Urban Design (WSUD) to mitigate the flow and water quality impacts of urban stormwater. Many different studies have shown their significant potential for pollutant removal, and proven in particular their effectiveness in removing suspended solids and heavy metals (Hatt et al., 2007a; Bratieres et al., 2008).

Biofiltration media requires a soil profile that can drain readily, support plant growth and capture a range of stormwater pollutants. These characteristics are sometimes in conflict and have been shown to be difficult to achieve in construction, with many systems found not to be constructed to their specification (Somes et al., 2007). Whilst theoretically, the media in biofiltration systems can range from sandy loam to coarse sand, some organisations recommend a certain type of media depending on the local conditions (e.g. climate, target pollutants, etc.); in Australia for example, the Facility for Advancing Water Biofiltration recommends the use of loamy sand (FAWB, 2008). Indeed, this particular media has shown to be very efficient in a series of thorough laboratory tests (Bratieres et al., 2008).

The characteristics desired in biofiltration systems are similar to those in soil profiles used to support turf systems such as golf greens, race courses or sporting fields. Experience in these industries has produced a series of guidelines for specifying and constructing systems, and suppliers are able to provide products of consistent quality. The approach adopted in the turf industry is to start with a sand base, and add known amounts of organic matter and fertiliser to sustain plant growth. It is hoped that adoption of this standard for biofiltration systems will simplify the media specifications and the sourcing of materials. This construction method will hopefully give greater control and precision over the final media characteristics, reducing the variability which is currently observed for loamy sand based media.

Throughout Melbourne a number of these systems have been constructed and whilst field tests confirm they are draining well and supporting plant growth, limited data is available to quantify their pollutant removal effectiveness. The aim of this study was therefore to test this alternative filter media, in order to give industry the confidence of a specification backed by independent scientific evidence. This filter media should (i) sustain plant growth, (ii) maintain hydraulic conductivity over time, and (iii) achieve effective pollutant removal.

This paper presents a one year column trial of sand based biofilters, and discusses the links between the nutrient removal performance and the hydraulic conductivity and plant growth measurements.

2 METHODS

2.1 Filter media specifications

In order to obtain a filter media which could be easily made and reliably and readily reproduced, it was suggested that the top layer of a washed sand be ‘ameliorated’ with appropriate organic matter, fertiliser and trace elements to sustain plant growth. The formula for the ‘ameliorant’ was based on experience from turf systems and biofiltration systems (Table 1).

<table>
<thead>
<tr>
<th>Name</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granulated poultry manure fines</td>
<td>50 kg/100m² filter area</td>
</tr>
<tr>
<td>Superphosphate</td>
<td>2 kg/100m² filter area</td>
</tr>
<tr>
<td>Magnesium Sulphate</td>
<td>3 kg/100m² filter area</td>
</tr>
<tr>
<td>Potassium Sulphate</td>
<td>2 kg/100m² filter area</td>
</tr>
<tr>
<td>Trace Element Mix</td>
<td>1 kg/100m² filter area</td>
</tr>
<tr>
<td>Fertiliser NPK (16.4.14)</td>
<td>4 kg/100m² filter area</td>
</tr>
<tr>
<td>Lime</td>
<td>20 kg/100m² filter area</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>82 kg/100m² filter area</strong></td>
</tr>
</tbody>
</table>

Table 1. Standard fertiliser constituents

Two triple-washed sands of different hydraulic conductivity were selected for the experiment, based on the hypothesis that the initial drainage rate could have an influence on the plant growth and therefore
on the treatment performance of the biofilters. These hydraulic conductivities were representative of the lower and higher values of the total range of properties observed during a preliminary pilot study of sands provided by a range of suppliers around Melbourne, Australia. Triplicate samples of both sands were tested to determine the particle size distribution and the ‘initial’ hydraulic conductivity (Table 2).

<table>
<thead>
<tr>
<th>Description</th>
<th>Sand with High Hydraulic Conductivity (HHC)</th>
<th>Sand with Low Hydraulic Conductivity (LHC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle size distribution (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fine Gravel 2.0 mm</td>
<td>Trace</td>
<td>Trace</td>
</tr>
<tr>
<td>Very coarse sand 1.0 mm</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Coarse sand 0.5 mm</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Medium sand 0.25 mm</td>
<td>53</td>
<td>50</td>
</tr>
<tr>
<td>Fine sand 0.15 mm</td>
<td>26</td>
<td>29</td>
</tr>
<tr>
<td>Very fine sand 0.05 mm</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Silt and clay &lt;0.05 mm</td>
<td>Trace</td>
<td>Trace</td>
</tr>
<tr>
<td>Drainage rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydraulic conductivity (mm/h)</td>
<td>733</td>
<td>627</td>
</tr>
<tr>
<td>Mean (mm/h)</td>
<td>680</td>
<td>375</td>
</tr>
<tr>
<td>Coefficient of variation (%)</td>
<td>7.8</td>
<td>5.7</td>
</tr>
</tbody>
</table>

Table 2. PSD and Hydraulic conductivity values for sand HHC and LHC. Samples were tested according to USGA 1993 / ASTM F1815 – 06.

2.2 Experimental set-up

The biofilter columns, tested in a greenhouse with a clear impermeable roof, were constructed from 375mm diameter PVC pipes, with a transparent Perspex top section allowing for plant growth and ponding of water (Figure 1). During construction, the filter media was not compacted mechanically, but rather allowed to compact naturally over time with water input.

Both types of sand were tested (i) without vegetation (as a control) and (ii) with Carex appressa (7 plants per column). This species was chosen because it was shown in previous trials (Bratieres et al.,
to be very effective, in terms of both growth rate and pollutant removal. In order to allow valid statistical comparisons, 5 replicates of each configuration were tested, resulting in a total of 20 biofilter columns.

2.3 Experimental procedure

2.3.1 Stormwater dosing/sampling regime

In field systems, the ‘ameliorant’ present in the top layer of the filter media is supposed to nourish the plants for 3-4 weeks, after which they are exposed to stormwater, which provides adequate ongoing nutrient supply. The columns were therefore watered with tap water for 4 weeks, before the stormwater dosing began.

The stormwater dosing regime was based on Melbourne’s climatic patterns and on a biofilter sized to 2.5% of its catchment area (typical of current local practice, Melbourne Water, 2005): 25L of semi-natural stormwater was applied twice weekly to each column. The target pollutant concentrations were matched to typical worldwide and Melbourne urban runoff concentrations (Table 3), as reported by Duncan (1999) and Taylor et al. (2005), respectively. The semi-natural stormwater was obtained by first mixing wetland slurry with dechlorinated tap water to achieve target TSS concentrations. Any deficit in other pollutants was then made up by adding appropriate chemicals.

<table>
<thead>
<tr>
<th>Sediment &amp; nutrients</th>
<th>Concentration (mg/L)</th>
<th>Heavy metals</th>
<th>Concentration (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Suspended Solids</td>
<td>TSS</td>
<td>150</td>
<td>Cadmium Cd</td>
</tr>
<tr>
<td>Total Phosphorus</td>
<td>TP</td>
<td>0.35</td>
<td>Chromium Cr</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>TN</td>
<td>2.10</td>
<td>Copper Cu</td>
</tr>
<tr>
<td>Total Dissolved Nitrogen</td>
<td>TDN</td>
<td>1.60</td>
<td>Manganese Mn</td>
</tr>
<tr>
<td>Ammonia</td>
<td>NH₃</td>
<td>0.26</td>
<td>Nickel Ni</td>
</tr>
<tr>
<td>Oxidised Nitrogen</td>
<td>NO₂</td>
<td>0.75</td>
<td>Lead Pb</td>
</tr>
<tr>
<td>Particulate Organic Nitrogen</td>
<td>PON</td>
<td>0.50</td>
<td>Zinc Zn</td>
</tr>
<tr>
<td>Dissolved Organic Nitrogen</td>
<td>DON</td>
<td>0.59</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. ‘Typical’ pollutant concentrations used for ‘semi-natural’ stormwater, based on review of worldwide (Duncan, 1999) and Melbourne (Taylor et al., 2005) data.

A total of four sampling runs (at two-monthly intervals) were conducted over the one year study, where composite water samples were taken from the inflow and outflow of each column. All the sampling runs were analysed for the nutrient species: Total Nitrogen (TN), Total Phosphorus (TP), ammonia (NH₃), oxidised nitrogen (NOₓ = nitrite NO₂ + nitrate NO₃), Total Dissolved Nitrogen (TDN), and Filterable Reactive Phosphorus (FRP) – a measure of dissolved phosphorus. Even though suspended solids and metals were also analysed for this study, this paper focuses on nutrient species.

2.3.2 Plant growth measurements

In order to record plant growth, the usual method is to progressively harvest a selection of the plants over time and measure their root and shoot characteristics (e.g. length, root diameter, weight... - see for example Read et al., 2008). Because plant harvesting could not be undertaken for this project (it was not viable, at the large column scale we were using, to create a sufficient number of replicate columns), it was decided to record shoot growth alone as a surrogate for plant growth. The average length of the 3 longest leaves per plant (7 per column) was used as an indicator for the size of each plant, and a median value was calculated for each column at each measurement time.

2.3.3 Hydraulic conductivity measurements

The evolution of hydraulic conductivity was monitored for each column using the top-down (constant head) method. The first test could only be undertaken after 5 months of dosing, when the plants were established enough to support the testing procedure. Further testing was undertaken after each stormwater sampling event, in order to minimise the possible effect of pollutant wash-out from the filter.
3 RESULTS AND DISCUSSION

3.1 Plant growth measurements

Visual assessment of plant health and the results of plant size measurements (Figure 2) both showed that adequate plant growth was sustained in all vegetated columns. Despite this, a difference in growth rate could be observed between the two sands: within the same time frame, plants growing in Sand LHC (of lower initial hydraulic conductivity) grew slightly taller and stronger than plants in Sand HHC (high initial hydraulic conductivity). However, statistical tests only showed a significant difference (p<0.1) in plant size between sand types in the months 4, 5, 9 and 10, reflecting the considerable variability between individual plants within each treatment (Figure 2).

![Figure 2. Plant height measurements for the 10 vegetated columns. The boxplots show the minimum, 1st quartile, median, 3rd quartile, and maximum of the distribution.](image)

The slightly taller plants for Sand LHC might be explained by the increased detention time (i.e. lower hydraulic conductivity), which results in both a higher moisture content in the column between rain/dosing events and a longer contact time with nutrient-rich water, which are both beneficial for plant growth.

3.2 Hydraulic conductivity measurements

A total of five hydraulic conductivity tests were undertaken over the length of the study. Figure 3 shows that the hydraulic conductivity of all columns decreased considerably over time (from several hundreds of mm/hr to less than 200 mm/hr), already in the time between the first and second test. This important initial drop in drainage rates could be explained by the impact of hydraulic compaction on a non-compacted filter media. Interestingly, statistical analyses (including ANOVA and t-tests) showed that sand type and status of vegetation had a, sometimes significant (p<0.05), influence on the level of hydraulic conductivity and on its temporal evolution.

3.2.1 Initial trends: April-June 2008

Up until June 2008, two trends were apparent: Sand HHC had a higher drainage rate than Sand LHC, and vegetated columns drained faster than unvegetated columns. Indeed, further analyses showed that there was a statistically significant difference (p<0.08) between vegetated and non-vegetated filters in April and June 2008. Whilst the first observation was to be expected (i.e. this reflects the initial drainage rate of the material), the second is less obvious, especially since the trend was opposite towards the end of the dosing year (December 2008). It is hypothesised that unvegetated columns were more prone to both compaction and surface sediment accumulation in the first months of dosing.
Indeed, the vegetation breaks up the surface layer with shoots, therefore partly reducing the effect of surface sediment accumulation, and also loosens up the inside of the filter media with roots, in turn creating macro-pores and preferential flow paths.

![Figure 3](image_url)

**Figure 3.** Median hydraulic conductivity for all four configurations. The duration of each individual test (i.e. the length of each segment) ranged from 50 to 80 consecutive hours.

### 3.2.2 Temporal evolution – ‘final’ drainage rates

**Non-vegetated columns.** After an initial drop in hydraulic conductivity due to surface clogging and compaction, the drainage rate for non-vegetated columns was almost constant between June and December 2008 (around 200 mm/hr, Figure 3). Indeed, the action of pouring stormwater into the columns in large amounts continually disturbs the surface clogging layer, which re-forms every time, and therefore keeps the drainage rate approximately constant. At this point in time, the level of the drainage rate was probably governed solely by the presence of the clogging layer. As a result, the difference between sand types (i.e. initial drainage rates) was not significant anymore after the first measurement ($p>0.15$). The very slight increase in hydraulic conductivity in the last two measurements could be related to the higher summer temperatures, which could have induced the formation of cracks and macropores (Hatt *et al.*, 2007b).

**Vegetated columns.** Figure 3 shows that the hydraulic conductivity in both types of vegetated columns decreased considerably over time. In fact, even though these configurations had a higher drainage rate at the start of the experiment, the ‘final’ values (between 30 and 50 mm/hr) dropped below the level for non-vegetated columns in December 2008. Indeed, besides the obvious accumulation of surface sediment and the hydraulic compaction, it is hypothesised that the strong decrease in drainage rates could also be explained by two other factors, related to the presence of vegetation. These two factors are particularly relevant in this study, given the extremely high plant density in the biofilter columns (equivalent to 65 plants /m²), compared to the use of 8-12 plants /m² in typical practice. Firstly, even though plant coverage can be beneficial, in that it retains part of the incoming sediment, it also reduces the impact of surface disturbance, and therefore could allow the quicker and more substantial formation of a sediment layer on the surface of the media. Furthermore, it could be possible that, with plant development, the root matting grows to be so dense below the surface, that it actually becomes a limiting factor for the drainage rate through the column.

Whilst both configurations (i.e. HHC and LHC sand) showed similar drainage rates at the start and at the end of the experiment, the type of sand (i.e. the initial drainage rate) had an influence on the rate of clogging. As the hydraulic conductivity values in LHC columns continually decreased over time ($p<0.1$), drainage rates in HHC columns were almost constant between June and October 2008, before dropping to a similar ‘final’ level in December 2008 (Figure 3). This observation could possibly
be explained by the development of the root matting underneath the filter media surface. Indeed, Section 3.1 showed that plants in HHC columns grew slower than those in LHC columns, meaning that the impact of the root matting, and therefore of the expected decrease in hydraulic conductivity, would have been delayed compared to that in LHC columns.

### 3.2.3 Relationship: plant growth – hydraulic conductivity

The previous observations for vegetated columns all indicate a possible relationship between plant growth and drainage rate: as plants grow (i.e. as their root system develops), the associated drainage rate of the filter media seems to decrease. The relationship could even be one of positive feedback, with the reduction in permeability resulting in greater retention of water and nutrients, leading to greater plant growth, and so on. As an indication of a possible link between the two variables, the relationship was analysed for every set of data collected (i.e. at a given time). Indeed, most plots of plant height versus hydraulic conductivity at a given time showed a negative relationship between the two variables, even though the trend was statistically significant (at the 5% level) only for the data collected in October and December 2008 (Figure 4).

![Graph showing the relationship between plant height and hydraulic conductivity for vegetated columns in October and December 2008.](image)

#### Figure 4. Relationship between plant height and hydraulic conductivity for vegetated columns. Note: The data analysis showed that there was no influence of sand type (i.e. initial drainage rate) in this relationship.

### 3.3 Water quality results – nutrient removal

#### 3.3.1 General removal efficiency

The water quality results for TP, TN, FRP and NO\textsubscript{x} from the 4 samplings undertaken throughout the duration of this study are displayed in Figure 5. The graphs show that, overall, phosphorus and nitrogen were well removed, with outflow concentrations below inflow concentrations in every sampling event for TP and TN. The lower removal performance observed for dissolved species (FRP and NO\textsubscript{x}) suggests that, although the total nutrient concentrations have been reduced by the biofilter, the composition of the pollutants has changed. Indeed, analysis shows that the dissolved fractions, represented by the ratios FRP/TP and TDN/TN, are higher in the outflow than in the inflow (Table 4). This indicates that, while most of the particulate fraction of nutrients is well removed by the biofilter, the dissolved fraction is not removed as well and is even possibly increased through desorption and chemical transformation processes (for example the breakdown of particulate into soluble forms).

For nitrogen in particular, it is apparent that the outflow is mostly in dissolved form (Table 4). Whilst this observation points to the fact that Particulate Organic Nitrogen (PON) is mostly removed via filtration and straining processes, it also suggests that ammonification (i.e. the transformation of organic nitrogen into NH\textsubscript{3}) and nitrification (i.e. the transformation of NH\textsubscript{3} to NO\textsubscript{x}) is occurring within the filter media. Indeed, the results showed that NH\textsubscript{3} was relatively well (and consistently) removed by the biofilters during the entire testing period: mean outflow concentrations for NH\textsubscript{3} were below 0.01mg/L (over 95% removal). This confirms that the nitrification process is enhanced in the biofilters, even without vegetation. Indeed, the microbial activity which is responsible for nitrification is not strongly dependent on symbioses with plants (Gerardi, 2002), and it is likely that biofilms exist even in the sand filters. After ammonification and nitrification, the nitrogen is in a more bioavailable form (NO\textsubscript{x}),
which is either taken up or is leached out at the next wetting event.

Figure 5. Water quality results for samplings 1-4: Mean outflow concentrations for TP, TN, FRP and NOx for each biofilter configuration (5 replicates).

<table>
<thead>
<tr>
<th>Inflow</th>
<th>Outflow</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRP / TP</td>
<td>TDN / TN</td>
</tr>
<tr>
<td>Sampling 1</td>
<td>43%</td>
</tr>
<tr>
<td>Sampling 2</td>
<td>17%</td>
</tr>
<tr>
<td>Sampling 3</td>
<td>42%</td>
</tr>
<tr>
<td>Sampling 4</td>
<td>33%</td>
</tr>
</tbody>
</table>

Table 4. Dissolved fractions of phosphorus and nitrogen, represented by the ratios FRP/TP and TDN/TN, respectively, in the inflow and outflow for Samplings 1-4.

### 3.3.2 Influence of vegetation and sand type

Figure 5 shows the apparent impact of the presence of vegetation on nutrient treatment performance. Indeed, from the first sampling onwards (25 weeks after planting), vegetation was always found to be a statistically significant factor (p<0.05) for TP, TN, FRP and NOx, with vegetated columns having significantly lower outflow concentrations than unvegetated columns. These results clearly demonstrate the importance of vegetation in nutrient removal by biofilters (Hatt et al., 2007a; Henderson et al., 2007; Bratieres et al., 2008). Indeed, plants can contribute to treatment efficiency in biofilters both directly, through plant uptake and maintenance of porosity, as well as indirectly, for example through influence on microbial communities (Read et al., 2008). The data analysis also revealed that the dissolved fraction of phosphorus (represented by the ratio FRP/TP) in the outflow was slightly higher in the non-vegetated columns than in the vegetated columns, showing that for similar filtration capacities, the adsorption capacities of the filter are enhanced by the presence of
vegetation, most likely due to the direct benefits of plants and their influence on conditions in the rhizosphere.

Except for FRP in the first two sampling events, there was no major difference in nutrient treatment performance between sand types.

3.3.3 Influence of other parameters: time, hydraulic conductivity and plant growth

Figure 5 shows that the removal performance of the biofilters significantly increased with time in most cases. It is hypothesised that this evolution could be related to the individual and interactive effects of the plant growth rate and the evolution of hydraulic conductivity in the columns. Because both variables are strongly influenced by time (Sections 3.1 and 3.2), their relationship with treatment performance was assessed independently (i.e. for each sampling run individually). Analysis of the results showed that, depending on the vegetation status of the column, the relationships were different (Figure 6).

Non-vegetated columns. Surprisingly, results in the form of scatter plots showed that the impact of hydraulic conductivity on pollutant treatment performance was either very slight or not noticeable (Figure 6). For example, pollutant outflow concentrations were constantly around 2 mg/L for TN and 1.6 mg/L for NOx, independently of the drainage rate of the column. These results for nutrient species challenge previous findings, which showed that pollutant treatment performance increased with lower drainage rates (i.e. higher contact time with the filter media), independently of the vegetation status (Bratieres et al., 2008).

Vegetated columns. It was found that for most pollutants, the outflow concentrations from vegetated columns seemed to be positively related to the level of hydraulic conductivity (e.g. TN and TP in Figure 6). It appears therefore that the enhanced pollutant treatment performance can partly be explained by the lower drainage rates. Indeed, for vegetated columns, a longer contact time with the filter media allows more time for plant uptake and for chemical and biological transformation processes. However, as discussed earlier (Section 3.2.3), there is also a strong relationship in vegetated columns between plant growth and hydraulic conductivity: drainage rates in vegetated columns decrease partly as a result of plant growth, and more specifically root growth, which enhances the direct uptake capacity of the plant, facilitating microbial development (Read et al., 2008). This means that whilst the increase in pollution treatment performance might partly be due to the decrease in drainage rate, and therefore to a longer contact time with the filter media, it is also indirectly explained by the effect of plant growth. As previously noted, we hypothesise that these two effects interact in a positive feedback loop.

Figure 6. Influence of hydraulic conductivity on TP and TN treatment performance in Sampling run 2. ◊: Non-vegetated columns, ■: Vegetated columns. Note: The trends were similar for other sampling runs. Trendlines were only shown where the regression was statistically significant at the 5% level.
4 CONCLUSIONS

This study tested an alternative bioretention system filter media, which could be reliably and easily specified and constructed from inert material, and which would (i) sustain plant growth, (ii) maintain hydraulic conductivity, and (iii) achieve effective pollutant removal.

The results showed that, independent of the type of sand used, plant growth was sustained in all biofilters, and that after one year of treatment (i.e. at the time of the last sampling event), the pollutant treatment performance of vegetated columns was comparable to other types of planted biofilters (e.g. loamy sand based filters, Bratieres et al., 2008). However, the results also showed that after one year of exposure to stormwater, the hydraulic conductivity of the filters had greatly deteriorated, in particular for the vegetated configurations. This could be a potential problem, given that, for stormwater treatment systems to be efficient also in the long term, the drainage rate needs to be maintained at a reasonable level to avoid by-pass of the treatment system in rain periods. Of course, it is important to keep in mind that these results have been obtained through a laboratory study, and therefore that they do not necessarily reflect what would happen in a field situation.

In conclusion, this study showed that vegetated sand based biofilters, built according to a simple formula using sand with ameliorants, could be used as a viable option for the treatment of stormwater. Because the type of sand did not have any significant impact on the long-term performance of the biofilters, the benefits of reproducibility and ease-of-implementation were found to equal or outweigh any disbenefits in terms of performance. In dry climates, where plants are more likely to suffer from the lower moisture retention capacity of sand in comparison to other soil based systems, it is advisable to adapt the design of the biofilter and for example to incorporate a submerged anoxic zone in the bottom of the filter (Kim et al., 2003; Zinger et al., 2007). Also, to counterbalance the inevitable clogging of the system and to ensure a reasonable level of treated annual flow, an option would be to include a large safety factor when sizing the biofilter.

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LIST OF REFERENCES


