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Comparison of Planted Soil Infiltration Systems for Treatment of Log Yard Runoff

Asa Hedmark1,2, Miklas Scholz3*, Par Aronsson4, Torbjorn Elowson1

ABSTRACT: Treatment of log yard runoff is required to avoid contamination of receiving watercourses. The research aim was to assess if infiltration of log yard runoff through planted soil systems is successful and whether different plant species affect the treatment performance at a field-scale experimental site in Sweden (2005 to 2007). Contaminated runoff from the log yard of a sawmill was infiltrated through soil planted with Alnus glutinosa (L.) Gärtnér (common alder), Salix schwerinii × viminalis (willow variety “Gudrun”), Lolium perenne (L.) (rye grass), and Phalaris arundinacea (L.) (reed canary grass). The study concluded that there were no treatment differences when comparing the four different plants with each other, and there also were no differences between the tree and the grass species. Furthermore, the infiltration treatment was effective in reducing total organic carbon (55%) and total phosphorus (45%) concentrations in the runoff, even when the loads on the infiltration system increased from year to year. Water Environ. Res., 82 (2010).

KEYWORDS: water management, water quality, treatment efficiency, total organic carbon, total phosphorus, water cycle, infiltration, wood industry, sawmill, Sweden.

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Introduction

Contaminated runoff from log yards is generated when water comes into contact with wood, woody debris, equipment, and vehicles at outdoor wood sorting, processing, and storage facilities (Woodhouse and Duff, 2004). It also is common to sprinkle logs with water to protect them from cracking and biological attack (Hedmark and Scholz, 2008). The contamination of the runoff depends on the specific conditions at the individual log yard; for example, the species of tree stored on the log yard, proportion of the runoff that has come in contact with stored wood, and dilution or pretreatment of the runoff before sampling. Typical runoff has little treatment before sampling. Typical runoff has little treatment before sampling, but pretreatment of the runoff before sampling is common. Treatment of the runoff that has come in contact with stored wood, and dilution or pretreatment of the runoff before sampling. Typical runoff has little treatment before sampling, but pretreatment of the runoff before sampling is common. Treatment of the runoff that has come in contact with stored wood, and dilution or pretreatment of the runoff before sampling. Typical runoff has little treatment before sampling, but pretreatment of the runoff before sampling is common. Treatment of the runoff that has come in contact with stored wood, and dilution or pretreatment of the runoff before sampling. Typical runoff has little treatment before sampling, but pretreatment of the runoff before sampling is common. Treatment of the runoff that has come in contact with stored wood, and dilution or pretreatment of the runoff before sampling. Typical runoff has little treatment before sampling, but pretreatment of the runoff before sampling is common. Treatment of the runoff that has come in contact with stored wood, and dilution or pretreatment of the runoff before sampling.
The distance between the drainage pipes was 4 m, and the distance from the drainage pipes to the edge of each plot was at least 2 m. The strips of land between the plots that were not irrigated functioned as indirect buffer strips. However, there was no control, with respect to root growth, beyond the border of each plot.

The eight plots were planted with four different species in 2003; two plots were planted with bare-rooted 50-to-80-cm-high *A. glutinosa*; two plots were planted with approximately 50-cm-high *S. schwerinii* ×*viminalis*; two were sown with *L. perenne* seeds; and two were sown with *P. arundinacea* seeds. *Salix schwerinii* ×*viminalis* planting was performed in a double-row system, with an approximate spacing of 0.75 and 1.5 m, respectively, between the rows and approximately 0.6 m within the row, resulting in a plant density of approximately 1.6 plants/m². The plant density for *A. glutinosa* was roughly 1 plant/m². The grasses were sown so that complete ground cover was achieved rapidly. Two replicates for each planted strip were considered appropriate, because the case study site was sufficiently homogenous throughout the soil profile.

The study site was left to mature until early spring 2005. By then, *A. glutinosa* and *S. schwerinii* ×*viminalis* had reached a height between 1.5 and 1.8 m. *Lolium perenne* had a height of approximately 0.4 m, and *P. arundinacea* measured 0.5 m. A plastic hose was placed on the surface of the plots for irrigation purposes. The hose was laid down in two arms on every plot, parallel to and between the drainage pipes. The hose was perforated to allow the irrigation water to trickle out as uniformly over each plot as practically possible. The drainage water was collected by the below-ground pipe system, which introduced preferential flow conditions, as a result of low flow resistance within the pipes compared with the soil. A previous study by Jonsson et al. (2006), discussing the runoff quality at this site, showed that the runoff was too low in nitrogen (approximately 1.3 mg/L) compared with carbon and phosphorus to allow for sufficient biodegradation to take place (Scholz, 2006). To address this potential problem, the plots were fertilized with 80 kg-N/ha in early July 2005. Each plot received 20 kg of fertilizer (15.5% nitrogen and 18% potassium) comprising nitrate matter, such as detritus and litter (Scholz, 2006). A previous study by Jonsson et al. (2006), discussing the runoff means for the log yard runoff (annual means

### Results and Discussion

**Log Yard Runoff Compared with Drainage Water.** Contaminant means and standard deviations for the log yard runoff and the drainage water from the plots have been summarized in Table 1. A comparison based on a one-way analysis of variance (ANOVA) between irrigation and drainage water for mean concentrations of total carbon, total inorganic carbon (TIC), total organic carbon (TOC), total phosphorus, and TSS for the four different species (two plots per species) was performed. The ANOVA showed that total carbon, TOC, and total phosphorus concentrations in the captured drainage water were lower and significantly different (p < 0.05) from the log yard runoff during the entire study period. This confirms that infiltration can be used successfully as a treatment method to reduce organic matter and phosphorus in log yard runoff, but findings indicate that the treatment efficiency over time could be limited for phosphorus.

For TIC, there was no significant treatment effect. Furthermore, the infiltration of the runoff also did not result in a statistically significant decrease in TSS concentrations. Despite the clear differences in mean concentrations of TSS in the log yard runoff and the drainage water from the planted plots (Table 1), the difference was not statistically significant in 2006. The low number of runoff samples (n = 4) and the generally high variability of TSS in the drainage water may explain the lack of statistical significance at p < 0.05.

In 2007, the infiltration did not lead to a decrease in TSS concentrations. On the contrary, the concentrations in the drainage water were higher than in the runoff for four of the eight plots, possibly because of a breakthrough of partly degraded organic matter, such as detritus and litter (Scholz, 2006).

The pH values were slightly higher for the drainage water (annual means = 6.8 to 7.5) compared with the log yard runoff (annual means = 6.3 to 7.4). However, both the runoff and the drainage water were in the range of what is commonly interpreted as an expected pH range (6 to 8) for receiving watercourses (Scholz, 2006). The drainage water generally had lower concentrations of total nitrogen (annual means = 0.8 to 3.4) than the log yard runoff (annual means = 1.3 to 4.1). Previous studies have shown that the concentration of total nitrogen in log yard runoff generally is low and that no treatment to reduce the concentration is necessary, except when the receiving watercourse is classified as “very nitrogen vulnerable” (Hedmark and Scholz, 2008). On the contrary, in this study, the soil was fertilized with nitrate in 2005. Modest fertilization was undertaken to prevent a shortage of bioavailable nitrogen, which could have led to reduced plant growth.

**Comparison of Drainage Water from the Different Plots.** The results from the infiltration experiment were analyzed to assess if there were any statistically significant differences in treatment efficiency for the different plant species. However, the concentrations of TOC, total phosphorus, and TSS in the drainage water from the plots with different plant species did not differ significantly at p < 0.05. The fact that the use of different plants did not significantly affect the removal efficiency (particularly regarding total phosphorus and TOC) strengthens the assumption that the microbial biomass contributed to the
purification performance (Scholz, 2006). However, no further investigations of bioactivity within the soil columns of the plots were undertaken.

There also were no differences in concentrations of total carbon for the species in the infiltration experiment. However, a two-sample t-test showed that the drainage water from the plots vegetated with S. schwerinii×viminalis had significantly higher concentrations of TIC than the drainage water from the plots planted with L. perenne. This was unexpected, because the infiltration treatment had no removal effect on TIC. This difference between the plant species could not be explained in this case study.

A statistical comparison with the two-sample t-test also was made for the water quality parameters of the drainage water from the plots vegetated with tree species (A. glutinosa and S. schwerinii×viminalis) compared with grasses (L. perenne and P. arundinacea). None of the assessed parameters (total carbon, TIC, TOC, total phosphorus, and TSS) were statistically significantly different (p < 0.05).

**Comparison of Treatment Efficiencies.** The findings confirmed that the infiltration treatment efficiency for log yard runoff was high with regard to TOC and that the removal of total phosphorus was high and relatively continuous during the experiment (Table 1). The removal of total carbon was relatively high, but the infiltration treatment was not successful for TIC. This difference between the tree and grass species. The research indicates that, under similar boundary conditions, an area of approximately 500 m² of yearly runoff from a log yard, to achieve the same retention of contaminants as in this study. Further research is required to address the inherent limitations of the study (i.e., no buffer strips between the plots, limited number of replicate plots, no unplanted control, and no nutrient analysis within each soil column), which was not designed as a rigorous experiment, but rather as an applied evaluation.

The treatment efficiencies of TSS decreased in 2007, which cannot be explained by an increased load of suspended solids in the irrigation water. The load of suspended solids only increased by 1.3% from 2006 to 2007. The change from sink to source of TSS cannot be explained by the small increase in load. However, it is known that some infiltration systems are sources for TSS, which is common for vertical downflow filtration systems (Ali-Senafy and Al-Otaibi, 2002; Scholz, 2003).

**Conclusions and Further Research**

The treatment efficiency for total phosphorus was relatively good, but further field-scale experiments are required to determine the long-term treatment effect at different phosphorus loads. Findings indicated no significant difference in treatment efficiencies when comparing four species of plants with each other. There also were no significant differences between the tree and grass species. The research indicates that, under similar boundary conditions, an area of approximately 0.5 ha of infiltration system would be required for every 10 000 m³ of yearly runoff from a log yard, to achieve the same retention of contaminants as in this study. Further research is required to address the inherent limitations of the study (i.e., no buffer strips between the plots, limited number of replicate plots, no unplanted control, and no nutrient analysis within each soil column), which was not designed as a rigorous experiment, but rather as an applied evaluation.

**Credits**

The authors thank Setra Trävaror AB (Heby, Sweden) and Karl Erik Önnesjös stiftelse för vetenskaplig forskning och utveckling (Karl Erik Önnesjö’s Foundation for Scientific Research and Development) (Norrköping, Sweden) for the financial support given during this study. The authors are grateful for the invaluable fieldwork and technical support provided by Richard Childs and

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**Table 1—Water quality parameters for the inflow and outflow of experimental soil infiltration systems planted with different species.**

<table>
<thead>
<tr>
<th>Sampling water type</th>
<th>Statistics*</th>
<th>Total carbon (mg/L)</th>
<th>TIC (mg/L)</th>
<th>TOC (mg/L)</th>
<th>Total phosphorus (mg/L)</th>
<th>TSS</th>
</tr>
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<tbody>
<tr>
<td>Irrigation water (inflow)</td>
<td>Mean 218.4</td>
<td>246.0</td>
<td>28.5</td>
<td>21.5</td>
<td>108.9</td>
<td>117.1</td>
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<td></td>
<td>Standard deviation 79.84</td>
<td>64.16</td>
<td>24.80</td>
<td>4.59</td>
<td>24.88</td>
<td>73.33</td>
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<tr>
<td>Outflow for Alnus glutinosa</td>
<td>Mean 109.4</td>
<td>131.6</td>
<td>20.9</td>
<td>23.3</td>
<td>88.5</td>
<td>106.4</td>
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<tr>
<td></td>
<td>Standard deviation 49.37</td>
<td>42.18</td>
<td>5.09</td>
<td>3.62</td>
<td>13.39</td>
<td>45.89</td>
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<tr>
<td>Outflow for Salix schwerinii×viminalis</td>
<td>Mean 114.4</td>
<td>134.0</td>
<td>23.0</td>
<td>24.8</td>
<td>91.3</td>
<td>109.1</td>
</tr>
<tr>
<td></td>
<td>Standard deviation 47.06</td>
<td>48.37</td>
<td>4.43</td>
<td>4.88</td>
<td>14.29</td>
<td>47.79</td>
</tr>
<tr>
<td>Outflow for Phalaris arundinacea</td>
<td>Mean 108.8</td>
<td>144.4</td>
<td>21.3</td>
<td>22.9</td>
<td>87.5</td>
<td>121.5</td>
</tr>
<tr>
<td></td>
<td>Standard deviation 41.54</td>
<td>40.62</td>
<td>5.37</td>
<td>3.46</td>
<td>7.07</td>
<td>40.28</td>
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<tr>
<td>Outflow for Lolium perenne</td>
<td>Mean 100.1</td>
<td>121.7</td>
<td>18.1</td>
<td>21.4</td>
<td>82.0</td>
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<tr>
<td></td>
<td>Standard deviation 44.46</td>
<td>43.06</td>
<td>6.71</td>
<td>3.78</td>
<td>12.23</td>
<td>41.96</td>
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* n = sample number.
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