Natural solutions for combined sewer overflow treatment in a Mediterranean Country, Portugal

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Introduction

The use of constructed wetlands (CW) is, when compared with traditional physical-chemical or biological plants, widely recognized as not only adequate for the treatment of wastewater but a more natural and environment friendly solution. CWs have been used for decades mostly for the treatment of domestic or municipal wastewater. Nevertheless, they have been recently applied to industrial and agricultural wastewater, landfill leachate and stormwater runoff (Vymazal, 2005).

During storm events, the flow in combined or partially separate sewer systems often exceeds the capacity of the wastewater treatment plants (WWTP) resulting in combined sewer overflows (CSO). Recently, studies have shown that the traditional approach to CSO management (including rainwater storage tanks, transport infrastructures and centralized wastewater treatment plants) is no longer sustainable (Balbo et al., 2010). Therefore, to reduce the detrimental impacts of CSO on receiving waters, enhanced treatment of these overflows may be required. CW are regarded as an attractive alternative and their high purification efficiency for CSO treatment has been proven in several studies (Uhl and Dittmer, 2005; Henrichs et al., 2007 and Van de Moortel et al., 2009).

For example, in Germany CSO treatment based on CW is already recognized as an appropriate technology and several systems have started operation in the last two decades (Uhl and Dittmer, 2005). In Italy, the first examples began to emerge recently (Balbo et al., 2010) while in Portugal, a Mediterranean country with a long dry period, there are still no applications of this technology. This has motivated the present research for gathering information and know-how required for the design of this type of infrastructures, namely aiming at the upgrade of overflow discharges in the Frielas Drainage Basin, close to Lisbon, Portugal. The Frielas WWTP is one of the major tertiary treatment installations in Portugal, serving 700 000 p.e (population equivalent). Nevertheless, during storm events, diluted effluents are directly discharged to the Trancão River. The use of “natural” treatment systems, such as CW, was considered to be a sustainable option for coping with such overflows. As such, two base alternative CW installations were evaluated “in situ”, namely in terms of organic matter and microorganism removal.
Materials and Methods

A pilot scale experimental setup, including four horizontal sub-surface flow constructed wetlands, was set at the Frielas WWTP, in Lisbon, to simulate CSO treatment. Each bed measures 555x361x400 mm and is exposed to the local weather conditions. Beds were organized into two groups (group 1 – CW1, CW2 – and group 2 – CW3, CW4) with each group being composed by two beds: one without vegetation (CW1 and CW3) and the other colonized with *Phragmites australis* (CW2 and CW4). The beds without vegetation acted as control. The formation of two identical groups intended to evaluate the effect of different hydraulic loads.

Gravel with diameters 4-8 mm was used as filling media, with a porosity of 30%. Feeding was conducted through a perforated pipe installed inside the bed. A throttle structure at the opposite end of the bed was installed at the bottom to allow the complete emptying of the filter and to set the maximum level allowed in the beds (about 5 cm below the surface).

Macrophytes where planted in the end of March 2011 to provide favorable weather conditions for establishment and growth. The beds were then inoculated for a period of two weeks, involving irrigation with wastewater twice a week. Adaptation growth was solid and quickly. *Phragmites* were about 20 cm when planted and two months later reached an average length of 60 cm.

The study of the start up phase was carried out from April to June 2011. The system was batch fed with the effluent from the grid chamber of the WWTP to simulate the pre-treatment in a full scale CW, thus contributing to prevent clogging problems. To assess the evaluation of the performance during start up phase, feeding was performed once a week. When there were no rain events prior to the feeding, CSO was simulated by a dilution with potable water (about 1/3 of sewage and 2/3 of water). The water used was previously stored for some days in order to assure the absence of free chlorine.

The method of operation was as follows:

- At the beginning of each event effluent samples of each bed where collected from the discharge for analysis.
- The beds where then completely emptied, measuring the volume discharged by each one.
- A reservoir continuously stirred was filled with CSO and a sample was collected for analysis.
- All beds where fed from the reservoir with group 1 receiving 10 L and group 2 receiving 20 L.
- After 1, 3 and 7 days, effluent samples were collected at the discharge of each bed and analysed to assess the effect of hydraulic retention time.

Each sample was analysed regarding Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Total Coliforms (TC) and Enterococcus. Experimental conditions such as temperature, redox potential, pH, conductivity and dissolved oxygen were also measured in situ.

Results and Discussion

The start up of CW for CSO treatment was analysed for a period of eight weeks. Figures 1 and 2 present the precipitation that occurred from April 19 to June 14, 2011, as well as the pollutant concentrations measured in each bed, namely regarding COD and TC. The experimental results show that the main COD removal occurred within the first 24 hours after each CSO event. This is probably due to the
removal of particulate material by filtration. During the remaining retention time a slower removal was observed. TC removal efficiency in terms of log decrease showed a more steady decay through the seven days of each event.

Figure 1 COD concentrations (CW1 to CW4)(April 19 to June 14, 2011).

During the first five weeks of operation COD removal efficiencies after 7 days increased 10 to 20% and seemed to stabilise after week 6, as presented in Figure 3. Vegetated beds were the most unstable.

Figure 2 Total Coliform concentrations (CW1 to CW4) (April 19 to June 14, 2011).

Figure 3 COD removal efficiencies after 7 days.
Table 1 presents the global COD and TC average removal efficiency after 7 days for all CW. These efficiencies were calculated with the result from the last 3 weeks, when stabilisation of the four CW had already been reached.

**Table 1 COD and TC average removal efficiencies after 7 days.**

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>CW1</th>
<th>CW2</th>
<th>CW3</th>
<th>CW4</th>
</tr>
</thead>
<tbody>
<tr>
<td>COD [%]</td>
<td>97</td>
<td>96</td>
<td>93</td>
<td>93</td>
</tr>
<tr>
<td>TC [log]</td>
<td>4.80</td>
<td>5.07</td>
<td>4.59</td>
<td>5.20</td>
</tr>
</tbody>
</table>

Differences between groups 1 and 2 in terms of COD efficiency removal were not very relevant, and thus hydraulic load did not seem to influence significantly the CW performance during start up. When comparing vegetated versus non vegetated beds differences were also not relevant, which may be due to the fact that plants were not completely established and mature. TC decreased by more than 4 logs after 7 days which is higher than expected. The obtained results are considered very promising, in terms of removal of organic matter and pathogens even during start up.

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