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Design comparison of experimental storm water detention systems treating concentrated road runoff

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Abstract

The aim was to assess the treatment efficiencies of experimental storm water detention (extended storage) systems based on the Atlantis Water Management Limited detention cells receiving concentrated runoff that has been primarily treated by filtration with different inert aggregates. Randomly collected gully pot liquor was used in stead of road runoff. To test for a 'worst case scenario', the experimental system received higher volumes and pollutant concentrations in comparison to real detention systems under real (frequently longer but diluted) runoff events. Gravel (6 and 20 mm), sand (1.5 mm), Ecosoil (inert 2 mm aggregate provided by Atlantis Water Management Limited), block paving and turf were tested in terms of their influence on the water quality. Concentrations of five-day at 20 °C ATU biochemical oxygen demand (BOD) in contrast to suspended solids (SS) were frequently reduced to below international secondary wastewater treatment standards. The denitrification process was not completed. This resulted in higher outflow than inflow nitrate-nitrogen concentrations. An analysis of variance indicated that some systems were similar in terms of most of their treatment performance variables including BOD and SS. It follows that there is no advantage in using additional aggregates with high adsorption capacities in the primary treatment stage.

Keywords: Biochemical oxygen demand; Detention; Gully; Nitrate; Road runoff; Storm water

1. Introduction

1.1. Sustainable drainage systems

'SUDS' is the acronym for Sustainable (Urban) Drainage System (British English) or also known as Best Management Practice (American English). A singular or series of management structures and associated processes designed to drain surface runoff as part of a sustainable strategy to predominantly alleviate capacities in existing conventional drainage systems in an urban environment is defined as SUDS (Butler and Davies, 2000; CIRIA, 2000; Scholz, 2006; SEPA, 1999).

New developments proposed for Brownfield sites or on the periphery of urban developments may be unable to obtain planning permission, if existing local sewers have no spare capacity for storm water drainage, and if the storm water discharge from the proposed site cannot be controlled. In the absence of suitable watercourses

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that can accommodate direct storm water discharges, alternative technologies such as 'at source' storm water storage and detention systems are required (Butler and Davies, 2000; Scholz, 2006).

Many existing catchments in Scotland (e.g. Glasgow and Edinburgh), which are served by combined sewerage, have the potential to increase local sewer capacity by disconnecting storm water at other sites within developed parts of the catchment (D'Arcy and Frost, 2001). Diversion of urban runoff before it enters the combined sewer into locally based storage devices such as the Atlantis Water Management Limited detention cell system has been shown to be a viable approach in many cases (Butler and Davies, 2000; CIRIA, 2000; Scholz, 2006).

Optimising the maintenance of SUDS structures is currently one of the greatest management problems. Mowing grass and removing litter and debris are the most time-consuming and therefore costly maintenance tasks (Jefferies et al., 1999; McKissock et al., 1999; Scholz, 2003).

Maintenance of all public above-ground SUDS structures is usually the responsibility of the local authority (The Stationery Office, 1968). These above-ground structures are defined as swales, ponds, basins and any other ground depression features. In contrast, the maintenance of below-ground SUDS structures is usually the responsibility of the local water authority. Below-ground SUDS structures include culverts, infiltration trenches, filter strips and below-ground detention systems (Butler and Davies, 2000; CIRIA, 2000; Nuttall et al., 1998; Scholz, 2006).

Storm water runoff is usually collected in gully pots that can be viewed as simple physical, chemical and biological reactors. They are particularly effective in retaining suspended solids (Bulc and Slak, 2003; Scholz, 2006). Currently, gully pot liquor is extracted once or twice per annum from road drains and transported (often over long distances) for disposal at sewage treatment works (Butler et al., 1995; Memon and Butler, 2002). A more sustainable solution would be to treat the entire road or car park runoff locally in potentially sustainable storm water detention systems such as below-ground storage systems and storm water ponds (Guo, 2001) reducing transport and treatment costs. Furthermore, runoff treated with storm water detention systems can be recycled for irrigation purposes.

Below-ground storm water storage and detention systems are defined as a sub-surface structure designed to accumulate surface water runoff, and where water is released from as may be required to increase the flow hydrograph. The structure may contain aggregates with a high void ratio or empty plastic cells and act also as a water recycler or infiltration device (Butler and Parkinson, 1997; Scholz, 2006).

A below-ground storm water detention system comprises a number of components forming a structure that is designed to reduce storm water flow. The system captures surface water through infiltration and other methods. The filtered storm water is stored below-ground in a tank. The water is often cleaned and filtered before it is infiltrated or discharged to the sewer or watercourse via a discharge control valve. The system benefits include runoff reduction of minor storms, groundwater recharge and pollution reduction. This detention system is predominantly applied in new developments (Scholz, 2006).

The effect of varying organic loading rates on the treatment performance of the complex biomass within most filter systems used for primary treatment is unknown. Moreover, an experimental study is required to assess the passive treatment performance of storm water detention systems.

Table 1
Packing order of the storm water detention systems; all building materials are inert

Height (mm)	System 1	System 2	System 3	System 4	System 5
861–930 (top)	Air	Air	Air	Block paving and 6 mm gravel (within spaces)	Air
791–860	Air	Air	Air		Turf
751–790	Air	Air	1.5 mm sand and 2 mm Ecosoil	1.5 mm sand and 2 mm Ecosoil	1.5 mm sand and 2 mm Ecosoil
711–750	Air	Sand	1.5 mm sand and Ecosoil	1.5 mm sand and 2 mm Ecosoil	1.5 mm sand and 2 mm Ecosoil
661–710	6 mm gravel	6 mm gravel	6 mm gravel	6 mm gravel	6 mm gravel
451–660	20 mm gravel	20 mm gravel	20 mm gravel	20 mm gravel	20 mm gravel
437–450	1.5 mm sand	1.5 mm sand	1.5 mm sand	1.5 mm sand	1.5 mm sand
431–436	Standard geotextile	Standard geotextile	Standard geotextile	Standard geotextile	Standard geotextile
201–430	Air	Air	Air	Air	Air
0–200 (bottom)	Water	Water	Water	Water	Water