Ecological Engineering 91 (2016) 16–23

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Microfaunal community in horizontal constructed wetlands with different design configurations

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ARTICLE INFO

Article history:
Received 15 September 2015
Accepted 6 February 2016

Keywords:
Wastewater
Treatment wetlands
Microfauna
Turbellaria
Rotifera
Biodiversity

ABSTRACT

In comparison with conventional activated sludge treatment systems, for which a large body of research has been carried out on their microfauna and their role in bacteria and pollutant removal, only a few studies have focused on microfaunal communities inhabiting constructed wetlands (CWs). The aim of this study was to evaluate the microfaunal communities of horizontal CWs with differing design configurations in order to determine those design factors affecting their abundance and community structure and to discover their role in bacteria removal. Total bacteria, ciliates, amoebae and metazoa were counted in the effluents of an experimental plant combining the most common design configurations of CWs. Three different hydraulic designs (hydroponic, free water surface—FWS and subsurface flow—SSF), presence *vs.* absence of vegetation, two plant species (*Typha angustifolia vs. Phragmites australis*) and two organic loading rates were compared. SSF and vegetation favoured bacteria removal whereas abundance of protozoa and diversity of metazoa was greater in FWS-planted wetlands. Microfauna community structure and bacterial removal were clearly affected by vegetation and flow type, although no significant relationships were observed between microfauna and bacteria abundance at the outflow. Therefore, other mechanisms such as filtration, sedimentation or adsorption, seem to be more important than predation in removing bacteria from constructed wetlands.

1. Introduction

Constructed wetlands (CWs) are extensive wastewater treatment systems in which pollutants are removed by biochemical processes, mainly due to the metabolism of bacteria developed within the reactor, as well as a complex community established inside the system, including protozoa and microscopic metazoa (Faulwetter et al., 2009). Microfauna composition has been further studied in activated sludge treatment systems and related to the performance and operational conditions of the system (Chen et al., 2004; Warren et al., 2010). However, microfauna community development depends on the treatment system considered, and studies on conventional activated sludge treatment cannot be generalised to others (Pérez-Uz et al., 2010). In this sense, research on microbial food webs of natural treatment systems is still very scarce.

Since microfauna need longer retention times than bacteria to develop (Lessard and Le Bihan, 2003), we could expect that a microfauna community in CWs with long retention periods (days) should diversify more than in activated sludge treatment reactors (Dopheide et al., 2009). In conventional activated sludge, ciliate biomass can represent up to 10% of the total (Madoni, 1994), while in horizontal subsurface flow constructed wetlands (HSSF CWs) some authors suggested that ciliates constituted up to 45% of total organic matter within the system (Puigagut et al., 2007a).

Microfauna play an essential role in bacteria removal in conventional treatment systems, like activated sludge or trickling filters (Curds, 1973; Warren et al., 2010). However, microfauna in extensive treatment systems have scarcely been studied, and only Stott et al. (2001) found evidence of the potential role of ciliates in removing pathogens from CWs. Although protozoan and metazoan grazing is supposed to influence the bacterioplankton community

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http://dx.doi.org/10.1016/j.ecoleng.2016.02.006
0925-8574/

structure and activity in eutrophic aquatic environments, its grazing efficiency depends on many factors (Hahn and Höfle, 2001; Barlet et al., 2014). Ciliate abundance and diversity in CWs seems to be influenced by the amount and quality of organic matter entering the system (Puigagut et al., 2007a, 2007b), plant presence (Puigagut et al., 2012), aeration (Zapater-Pereyra et al., 2014) or biofilm development (Stott and Tanner, 2005). Similarly, for metazoa Vymazal et al. (2001) found organisms with a decreasing saprobity index from raw wastewater to effluent of subsurface flow (SSF) CWs and also a more variable biota within the beds, revealing the heterogeneity of microhabitats in those systems (Giordano et al., 2014). For these reasons, some studies have suggested that microfauna can be used as indicators for assessing environmental conditions in SSF CWs (Decamp et al., 1999).

Environmental conditions and removal mechanisms within a CW are strongly determined by its design configuration (Hijosa-Valsero et al., 2012), which could influence their ecology in terms of microbiota structure and microbial food web (Barlet et al., 2014). The aim of this study was to characterise the structure and abundance of the microfaunal communities in several horizontal CWs with different design configurations, and their potential role controlling bacterial removal. For this purpose, an experimental plant combining eight different and most commonly used design configurations was assessed. Thereby, design parameters such as organic loading rate, presence or absence of vegetation, plant species and flow type have been evaluated under the same climatic and water quality conditions.

2. Methods

2.1. Experimental pilot plant

Eight mesocosm-scale CWs (80 cm wide, 130 cm long and 55 cm high) were placed inside the facilities of the León wastewater treatment plant (WWTP) in the northwest of Spain. Each CW devised a design characteristic so that pairwise comparisons between wetlands differing in only one design parameter can be made as shown in Fig. 1. CW1 and CW5 were constructed as soilless wetlands with *Typha angustifolia* and *Phragmites australis*, respectively. In these two wetlands, water depth was 30 cm and garden net cylinders supported plant species. *T. angustifolia* nor *P. australis* are floating macrophytes, but these two wetlands were considered in order to evaluate the effect of plant species. CW2, CW3 and CW4 were designed as free water surface (FWS) systems with 25 cm of siliceous gravel (d_{60} = 7.3 mm) and 50 cm water depth (25 cm of water ponding above the gravel surface). CW2 was a strict FWS with inlet and outlet pipes located on the surface of the wetland. In CW3 and CW4, the outlet pipe was placed at the bottom of the container, thus forcing the water to flow through the gravel. CW2 and CW3 were planted with *T. angustifolia* while CW4 was an unplanted system. CW6, CW6′ and CW7 were typical SSF wetlands (with surface inlet and subsurface outlet), with a 50 cm layer of siliceous gravel (d_{60} = 7.3 mm) and 45 cm water depth. CW6′ received a twofold higher organic load than CW6. CW6 and CW6′ were planted with *P. australis* whereas CW7 was an unplanted system.

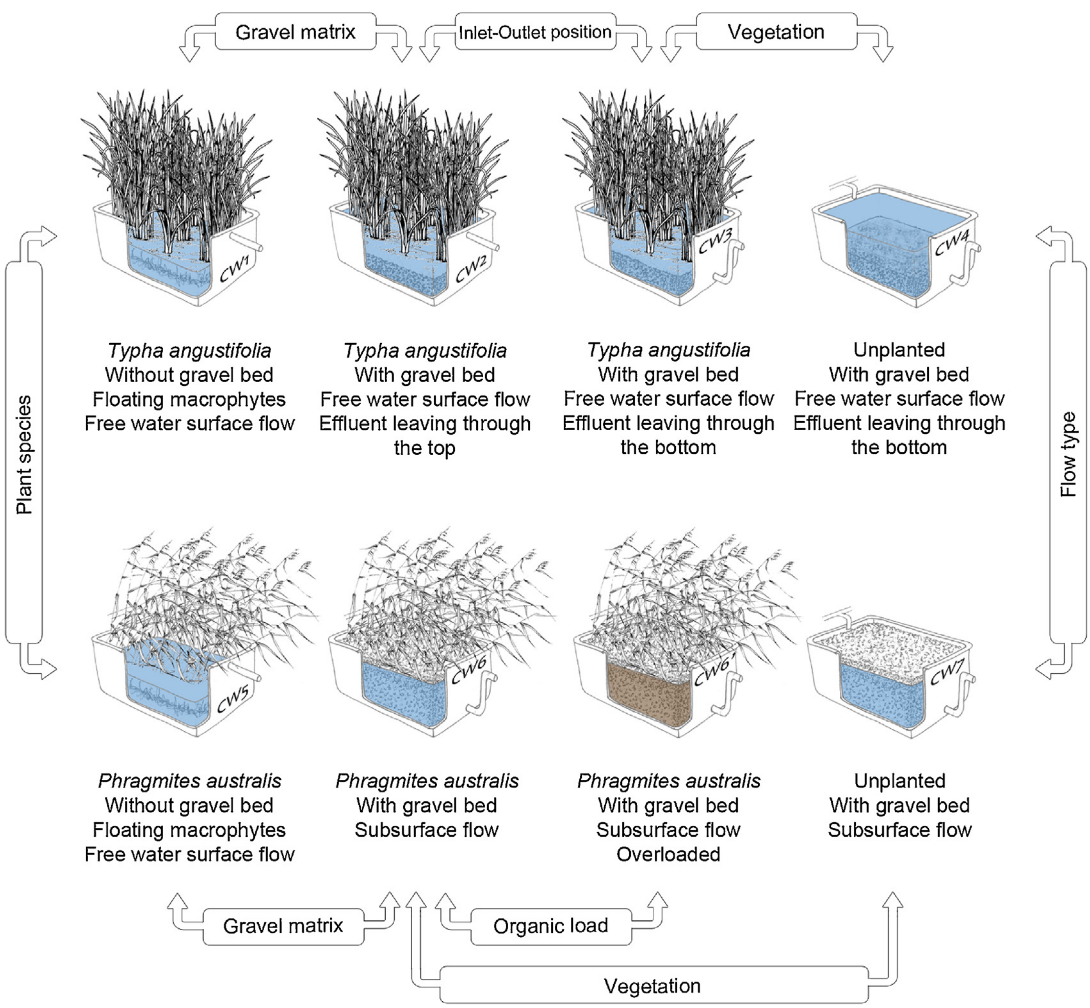

Fig. 1. Configuration of the experimental plant and the effects evaluated among wetlands.