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# Suspended particle and pathogen peak discharge buffering by a surface-flow constructed wetland

Bram T.M. Mulling[a,c,*], Rob M. van den Boomen[b], Harm G. van der Geest[a], Joost W.N.M. Kappelhof[c], Wim Admiraal[a]

[a] University of Amsterdam, Institute for Biodiversity and Ecosystem Dynamics, Department of Aquatic Ecology and Ecotoxicology, Science Park 904, 1098 XH Amsterdam, The Netherlands

[b] Witteveen+Bos, Van Twickelostraat 2, 7411 SC Deventer, The Netherlands

[c] Stichting Waternet, Korte Ouderkerkerdijk 7, 1096 AC Amsterdam, The Netherlands

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ABSTRACT

Constructed wetlands (CWs) have been shown to improve the water quality of treated wastewater. The capacity of CWs to reduce nutrients, pathogens and organic matter and restore oxygen regime under normal operating conditions cannot be extrapolated to periods of incidental peak discharges. The buffering capacity of CWs during peak discharges is potentially a key factor for water quality in the receiving waters. Therefore, the aim of the present study was to investigate the behaviour of peak discharges of suspended particles, (associated) physiochemical parameters and pathogenic organisms from a wastewater treatment plant (WWTP) in a full scale constructed wetland (CW). By mixing clarified water and sludge rich water from the settlement tank of the WWTP, the suspended particle concentration was increased for 8 h from ±3.5 to ±230 mg $L^{-1}$, and discharged into a full scale horizontal surface flow constructed wetland. An increase of suspended particle concentration following the peak discharge concurred with increases in turbidity and oxygen demand, total nutrient load (nitrogen, phosphorus and carbon) and pathogens (*Escherichia coli* and *Enterococci*). Temperature, pH, conductivity and dissolved nutrient concentrations (nitrogen, phosphorus and carbon) were however unaffected by the initial peak discharge. After retention in the unvegetated ponds (the first CW compartment) the applied suspended particle peak with a total load of 86.2 kg was reduced by >99%. Similar peak buffering was observed for the turbidity, oxygen demand and settable volume. Simultaneously dissolved nutrient concentrations increased, indicating partial mineralization of the suspended particles during retention in the unvegetated ponds. The peak buffering of pathogens was lower (40–84%), indicating differences in removal processes between other suspended particles and pathogens. The results indicated that the suspended particles were probably mostly removed by sedimentation and mineralization, where pathogens were more likely buffered by biofilm retainment, mortality and predation, mainly in reed ditches. After passing through the total CW the residuals of the suspended particle peak discharge were temporal increased concentrations of inorganic carbon (IC), $NH_4$ and *E. coli* (respectively 11%, 17% and 160% higher than steady state concentrations). The observations support the positive role of CWs for effective buffering of wastewater discharge peaks.



* *Corresponding author*. P.O. Box 94248, 1090 GE Amsterdam, The Netherlands. Tel.: +31 205258265.
E-mail address: b.t.m.mulling@uva.nl (B.T.M. Mulling).

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## 1. Introduction

Constructed wetlands (CWs) are man-made ecological systems that are used in a wide variety of applications to improve water quality. Since the first attempts to use CWs for water quality improvements of untreated wastewater in the early 1950s, the development and use of CWs for wastewater treatment has spread across the world (Sundaravadivel and Vigneswaran, 2001). Nowadays, CWs are often used as an additional polishing step to reduce the potential impact of treated wastewater on receiving surface waters (Kadlec and Wallace, 2008; Vymazal, 2005a). CWs are designed to utilize several occurring physical, chemical and biological processes, like sedimentation and microbial degradation to reduce the negative impact of various constituents in (treated) wastewater. It is demonstrated that concentrations of nutrients (especially nitrogen and phosphorus), organic compounds, suspended particles, pathogens, heavy metals and hormones (Kadlec and Wallace, 2008) are significantly reduced by CWs: under normal operating conditions removal efficiencies for organic compounds and suspended particles range between 60 and 95%, while nutrient removal efficiencies are generally below 60% although higher efficiencies up to 90% have been reported (Zhang et al., 2011; Zurita et al., 2009; Vymazal, 1996, 2007; Fisher and Acreman, 2004; Cameron et al., 2003). Removal of pathogens (including bacteria, viruses and parasites) is generally high, with removal efficiencies ranging between 80 and >99% (Foekema, 2012; Reinoso et al., 2008; Vidales-Contreras et al., 2006; Vymazal, 2005b). The removal of hormones like oestrogens generally ranges between 35 and 95% (Cai et al., 2012; Song et al., 2011; Shappell et al., 2007; Gray and Sedlak, 2005). In the Netherlands, several CWs are operational for more than 10 years. From monitoring studies it is demonstrated that in these CWs concentrations of nitrogen and phosphorous in the effluent of tertiary treatment WWTP are reduced with 10–25% and 2–40% respectively (Van den Boomen and Kampf, 2012), pathogens with a log 2.0–2.5 (>99%) (Foekema, 2012; Van den Boomen et al., 2012) while organic and suspended matter reduction is very limited (Van den Boomen and Kampf, 2012; Van den Boomen et al., 2012). The removal efficiencies mentioned above are mainly based on measurements during normal operating conditions. The removal efficiency is however affected by the hydraulic and pollutant loading, with increasing loadings causing decreasing efficiencies (Vymazal, 2007; Fisher et al., 2009; Toet et al., 2005). Present knowledge so far is thus based on relative constant loading levels and monthly monitoring data, and little is known about removal efficiencies during incidental peak discharges.

Kruit et al. (2009) showed that incidental peak discharges carry elevated loads of suspended particles (sludge) and occur a few times a year at several WWTPs in The Netherlands, primarily caused by storm water inflow and malfunctioning of the wastewater treatment plant.

The present study aims to investigate the behaviour of incidental peaks in concentrations of suspended particles in a constructed wetland system and discuss the major processes affecting peak behaviour in individual CW compartments. A suspended particle peak was induced and discharged into a full scale horizontal flow constructed wetland receiving secondary-treated municipal wastewater. The suspended particle peak was monitored in the CW by analysing selected physicochemical parameters, concentrations of suspended particles, organic matter, nutrients and pathogens at the in- and outflow of the two different CW compartments, unvegetated ponds and reed beds (*Phragmites australis*).

## 2. Materials and methods

### 2.1. Design of the constructed wetland

This study was carried out in a full scale horizontal surface flow constructed wetland (CW) located in Grou, The Netherlands (N53 05.535 E5 49.050). The CW was constructed in 2006 and receives secondary-treated municipal (mainly domestic) wastewater with a constant hydraulic loading of 1200 $m^3$ $day^{-1}$. After inflow of treated municipal wastewater from a settlement tank, the water flows through the CW consisting of a series of three unvegetated ponds and four parallel reed beds (Fig. 1). At the end of the reed beds the water is pumped into an ecological buffer zone which is in open connection with the receiving surface water (channel) (Fig. 1).

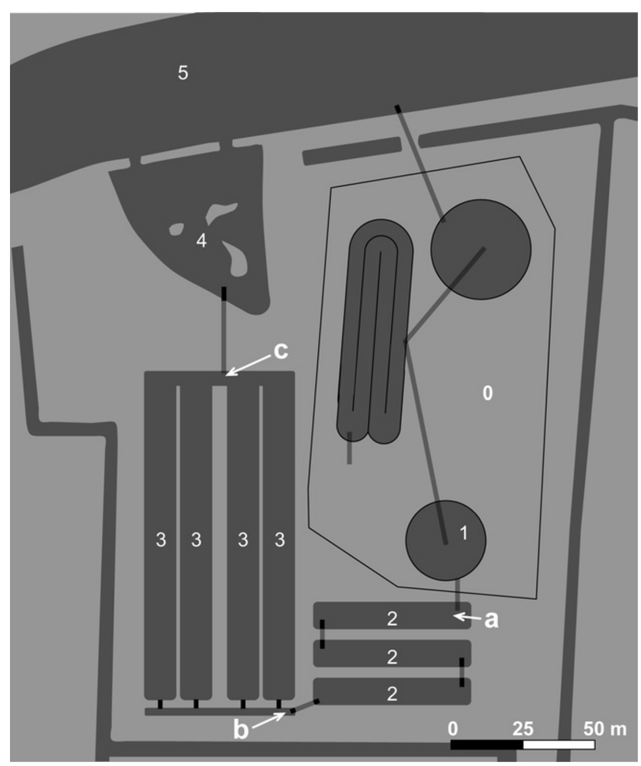


**Fig. 1 – Map of the WWTP in Grou, the Netherlands (0) with a settlement tank (1) which discharges treated municipal wastewater into a CW consisting of unvegetated ponds (2), reed beds (3) and an ecological buffer zone (4) which is in open connection with the receiving channel (5). Sampling points were located at; PONDS-IN (a), PONDS-OUT (b), REED-BEDS-OUT (c).**