Biodegradation of Urban Stromwater Pollution in a Sequence of Constructed Porous Riffles in a Mediterranean Creek

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Keywords
Pollution • Biodegradation • Porous medium • Urban creek

1 Introduction

Our aim was to provide guidelines for restoring and enhancing the self-purification capacity of Mediterranean urban creeks (no summer flow), in particular their resilience to pollution induced by discharges of combined sewer overflows (CSO). Urban stormfall discharges from combined sewer harshly impact creeks both morphologically, due to the erosion process linked to an unbalance between water flow and sediment load, and biochemically by the outflows of wastewater and polluted runoffs from urban areas. The erosion process alters the riverbed porousness and may lead to the pollution associated water table. Polluted water will also circulate in creek without any dilution during dry periods, and reach downstream perennial water bodies and thus jeopardising some ecological and recreational services.

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2 Materials and Methods

Chaudanne creek, located at Grézieu-la-Varenne (Rhône, France), drains a 2.7 km^2 watershed. Its land use is 90% rural (meadows and crops) and 10% urban. The setup consists in three sand deposits naturally stored behind three porous weirs originally designed to control the incision process. Weirs are made of wood logs, allowing water circulation through a sand mass on average 1 m thick and about 2 m wide. A well (Ø 75 mm) network is used to monitor surface water quality (S_i wells) up- and downstream, and in hyporheic zone (H_i wells) of sand deposits, 30 cm below sand surface. This setup is described in Fig. 1.

Each well hosts a multi-parameter probe (Ysi 6920V2©) logging dissolved oxygen, temperature, electrical conductivity, pH and redox potential at 10 min time-step, over a full hydrological cycle. Weekly water samplings in wells and in creek allowed the monitoring of pollution indicators (NO_3^-, NO_2^-, NH_4^+, PO_4^{3-} and COD). Creek and CSO discharge flows were measured by the field observatory consortium (OTHU[1]). Nitrogen compounds are expressed in nitrogen equivalents to compare quantities of various nitrogenous forms. Measurement points were pooled by station (0 to 4, see Fig. 1.) to analyze the global variation ranges of pollution indicators in each sand deposits.

[1]OTHU: Observatoire de Terrain en Hydrologie Urbaine (http://www.graie.org/othu/).

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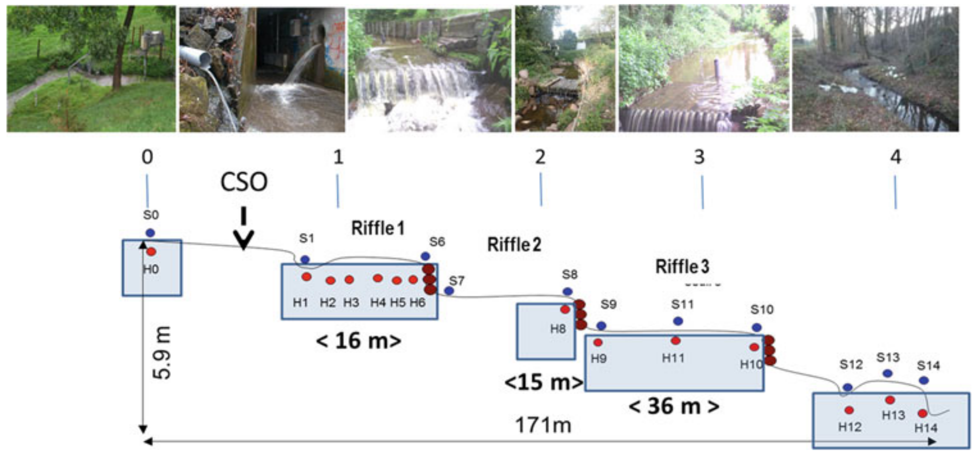

Fig. 1 Longitudinal cross-section of the set-up on the Chaudanne creek. Points related to the letters (S)urface and (H)yporheic are the points of continuous measurement and for water sampling. Photos: upstream natural riffle (0), CSO outlet "urban disposal", three constructed riffles (1, 2, and 3), downsteam natural riffle (4)

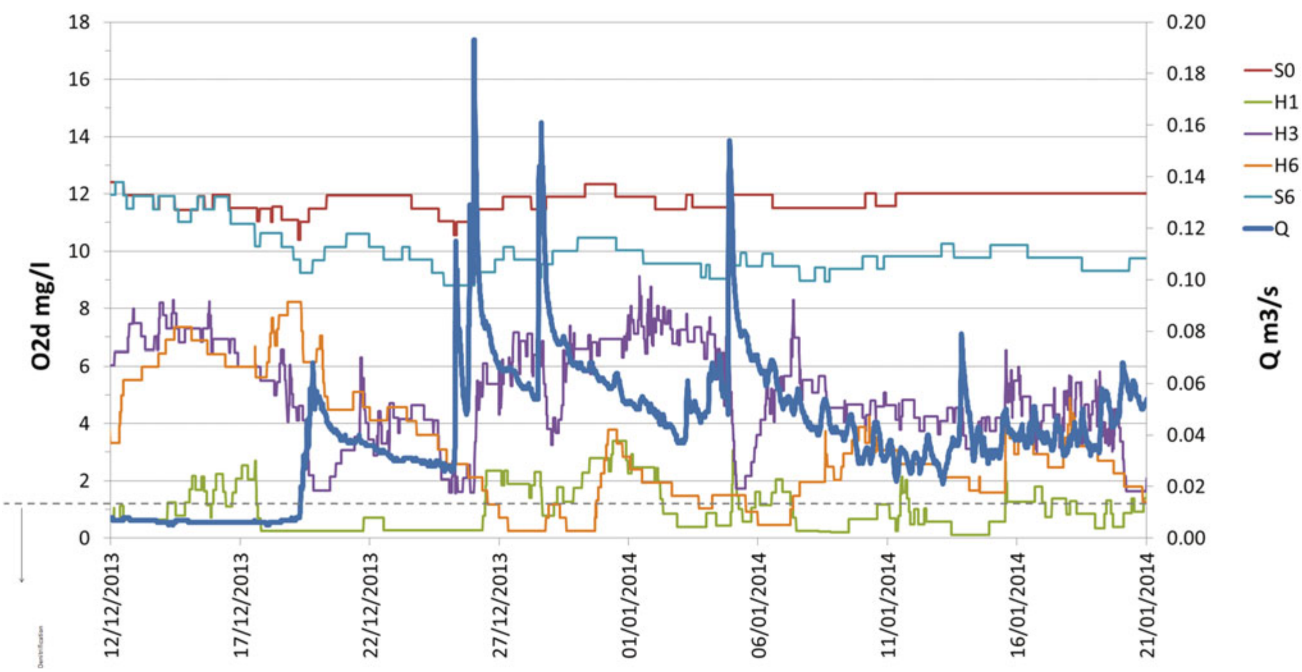

Fig. 2 Variations of the dissolved oxygen concentration with time and space at wells H_1 to H_6 in the constructed riffle 1. ES00 stands for surface dissolved oxygen concentration. The dash line of 1 mg/L is the threshold for the denitrification process

3 Results and Discussion

3.1 Pollution Trapping Effect by Accumulated Sand Layers

Nitrogen is essentially present under NO_3^- form, followed by NH_4^+ then NO_2^-. NH_4^+ has the highest concentrations at stations 1, 2 and 3 compared to the natural stations 0 and 4. Similarly, a poor quality zone mainly occurs in the three stations located in constructed riffles. Organic matter released from the CSO during rainy season explains the NH_4^+ content at station 1. NO_3^- contents indicate a poor water quality at all stations without any discriminating effect of the constructed riffles. This results from the agricultural activity taking place in the watershed: NO_3^- concentration is high during the winter rainy season, but decreases in spring because of absorption by active vegetation. NO_2^- distribution is comparable to NH_4^+ with 15 times lower concentrations. NO_2^- comes from NH_4^+ oxidation and very rapidly turns into NO_3^- by nitrification. PO_4^{3-} and COD have a similar behavior to NH_4^+. In surface water the concentrations of pollution indicators are in the middle to good class. Hyporheic zone at natural station 4 does not exhibit any impact, whereas natural weirs concentrate organic and metallic pollutants

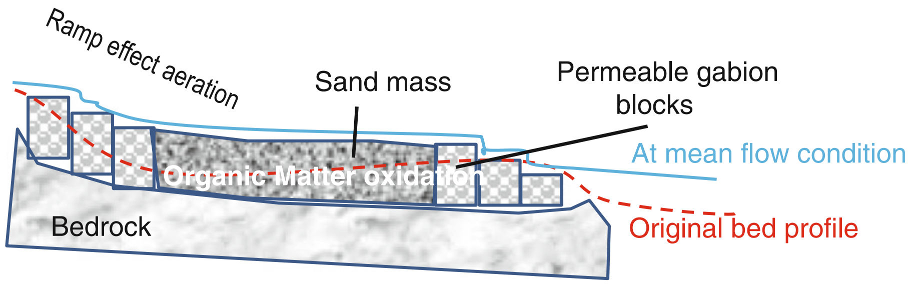

Fig. 3 Prospective design of one unit of a constructed riffle to trap organic matter during low flows and process it by oxidation during medium flow period

(Zhang 2014; Namour et al. 2015). At low natural flows, constructed riffles trap very efficiency the pollution discharged by the CSO device.

3.2 Aerobic Biodegradation in Man-made Weirs

Bacteria use dissolved oxygen to degrade organic matter. Dissolved oxygen content in surface water (S_1) is on average 12 mg/L, which is the saturation value for the studied period (see example from Fig. 2). CSOs release organic matter and oxygen-depleted water. Oxygen depletion does not persist because natural flow brings oxygenated water from upstream. At well H_1, dissolved oxygen content does not exceed 4 mg/L. In fact, the upstream part of sand deposit traps the organic matter flows which infiltrate through sediment, driven by the water flux. At well H_3, average dissolved oxygen concentration is about 5 mg/L. Difference with the surface (12 mg/L) indicates an oxygen consumption related to biodegradation activity. At well H_6, content varies from near 0 to 8 mg/L. Water leaving the first constructed riffle (1) is therefore depleted in dissolved oxygen. This could be managed, for example, through a passive aeration ramps downstream each constructed riffle.

4 Conclusion and Perspectives

Constructed riffles seems to have a dual function: (i) trap the pollution delivered by a CSO and avoid its downstream dissemination; and (ii) biodegrade on-site this pollution. During the study, the natural regeneration of the sand deposit during large flood events was observed. It is possible to improve the system by replacing the artificial weirs with ramps of gabions[2] that maintain hydraulic continuity and produce more efficient aeration than waterfalls (Khdhiri 2014; Khdhiri et al. 2014). Constructed riffles should be tested on other small creeks in parallel with a design assistance model. A design project is proposed in Fig. 3.

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[2]Gabion: metal cage filled with rocks.