



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

Pascal Breil, Jonathan Gervais, Philippe Namour, Marie-Noëlle Pons, Olivier Potier

► To cite this version:

Pascal Breil, Jonathan Gervais, Philippe Namour, Marie-Noëlle Pons, Olivier Potier. Biodegradation of Urban Stormwater Pollution in a Sequence of Constructed Porous Riffles in a Mediterranean Creek. *Advances in Science, Technology & Innovation*, pp.145 - 147, 2018, 9783319705484. 10.1007/978-3-319-70548-4_48 . hal-03974430

HAL Id: hal-03974430

<https://hal.inrae.fr/hal-03974430>

Submitted on 5 Feb 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

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

Pascal Breil, Jonathan Gervais, Philippe Namour, Marie-Noëlle Pons, and Olivier Potier

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.

2 Materials and Methods

Chaudanne creek, located at Grézieu-la-Varenne (Rhône, France), drains a 2.7 km² 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 (NO₃⁻, NO₂⁻, NH₄⁺, PO₄³⁻ and COD). Creek and CSO discharge flows were measured by the field observatory consortium (OTHU¹). 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.

P. Breil · J. Gervais · P. Namour (✉)
Irstea, 5 Rue de La Doua, 69626 Villeurbanne, France
e-mail: philippe.namour@irstea.fr

P. Breil
e-mail: pascal.breil@irstea.fr

J. Gervais
e-mail: jonathan.gervais@univ-lyon1.fr

M.-N. Pons · O. Potier
Université de Lorraine, LRGP ENSIC CNRS, B.P. 20451,
54001 Cedex Nancy, France
e-mail: marie-noelle.pons@univ-lorraine.fr

O. Potier
e-mail: olivier.potier@univ-lorraine.fr

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

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), downstream natural riffle (4)

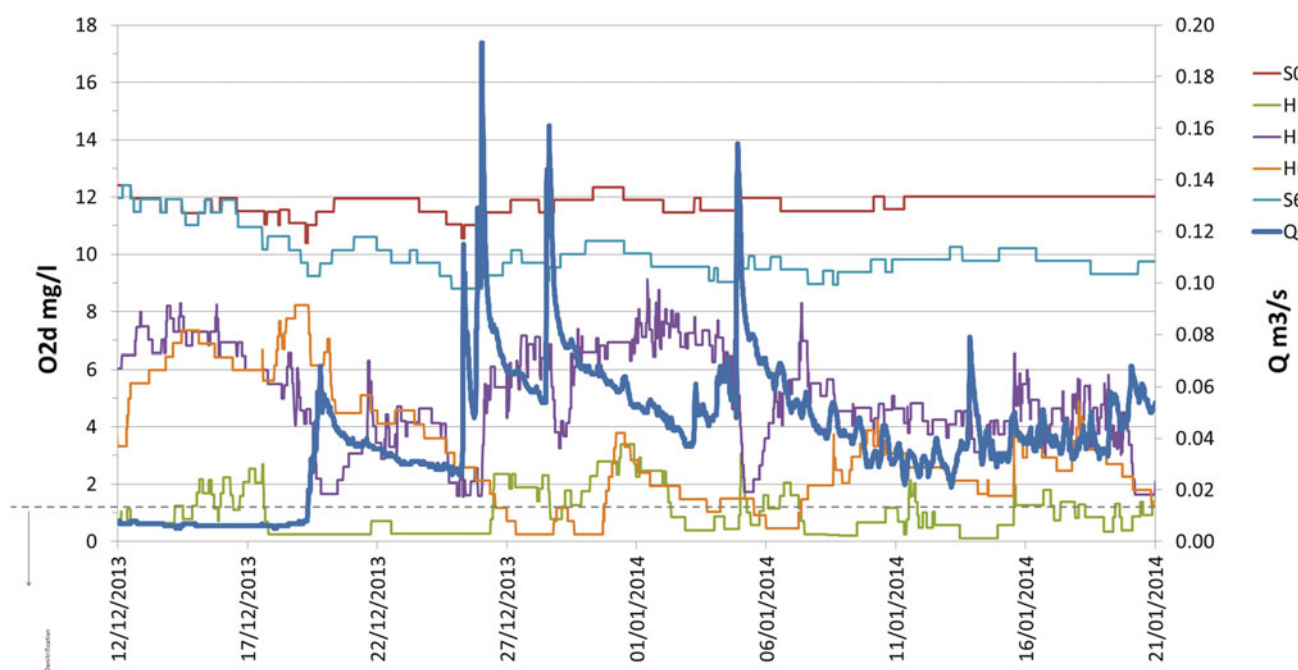
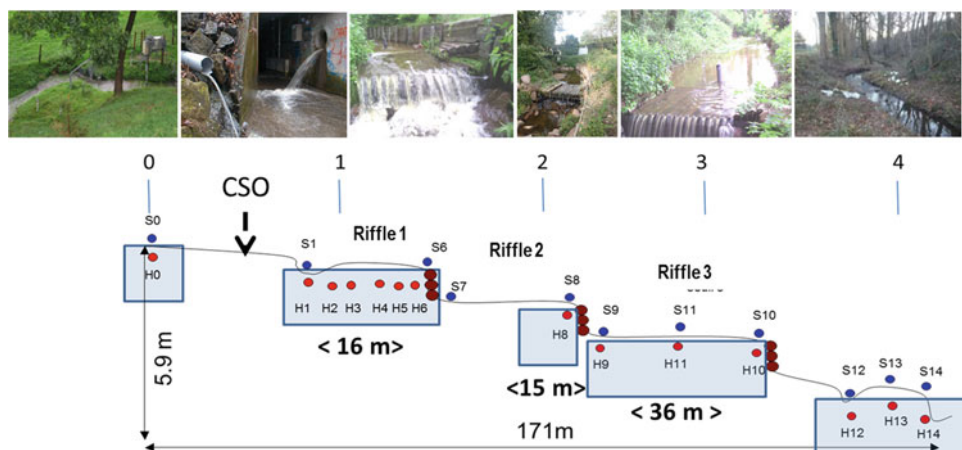


Fig. 2 Variations of the dissolved oxygen concentration with time and space at wells H₁ to H₆ in the constructed riffle 1. ES00 stands for surface dissolved oxygen concentration. The dash line of 1 mg/L is the threshold for the denitrification process

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

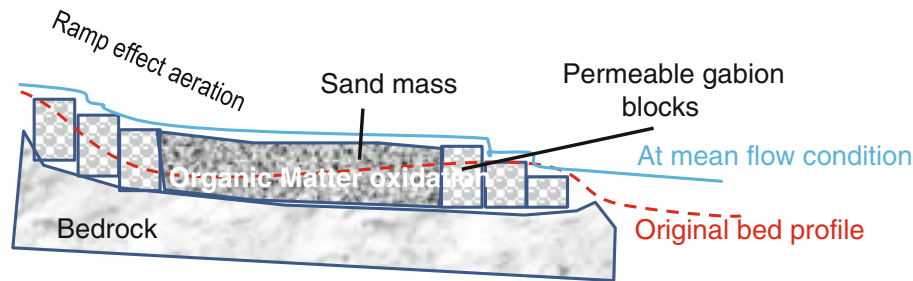


Fig. 3 Prospective design of one unit of a constructed riffle to trap organic matter during low flows and process it by oxidation during medium flow period

(Zhang 2014; Namour et al. 2015). At low natural flows, constructed riffles trap very efficiently 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 seem 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 gabions² 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.

Acknowledgements The authors thank the French National Research Agency (EPEC ANR-10-ECOT-007), the Field Observatory in Urban Water Management (OTHU, www.othu.org/, FED 4161), the Greater Lyon, the Rhône-Mediterranean & Corsica Water Agency, and the Auvergne-Rhône-Alpes Region for their scientific and financial support.

References

- Khdhiri H. Epuration en eaux courantes: évaluation et modélisation de la capacité d'oxygénation dans les cascades et les chutes d'eau. *Doctorat de l'université de Lorraine* 2014. <http://www.theses.fr/2014LORR0216>.
- Khdhiri H, Potier O, Leclerc JP. Aeration efficiency over stepped cascades: better predictions from flow regimes. *Water Res.* 2014;55 (15):194–202.
- Namour Ph, Eschach D, Schmitt L, Moulin B, Fantino G, Bordes C, Breil P. Stream pollution concentration in riffle geomorphic units (Yzeron basin, France). *Sci Total Environ.* 2015;532:80–90.
- Zhang Y. Epuration naturelle : de la rivière à la zone humide de rejet. *Doctorat de l'Université de Lorraine* 2014. <http://www.theses.fr/2014LORR0302>.

²Gabion: metal cage filled with rocks.