Additional ecological services of CSO-CW besides water treatment: modelling CSO-CW behaviour for urban runoff management

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INTRODUCTION

Combined sewer overflows (CSOs) have been recognized as a dangerous pollutant source for receiving water bodies, and CSO treatment is hence very important to promote a sustainable development. Constructed wetlands (CWs) are starting to be considered as a viable and eco-sustainable technology to treat CSOs (Meyer et al., 2013). However, CSO-CW provides other ecological services beside to water treatment: (i) urban runoff management, (ii) biodiversity increase, (iii) social services (e.g., recreation). Here we have developed a mathematical model of a real case study to highlight the functioning of CSO-CW as also a flood mitigation system, which promotes an urban runoff management from a post-development (high peak, short duration) back again to a pre-development (low peak, high duration) hydrograph influent to the river (Fletcher et al., 2013).

METHODS

The experimental case study is located in Gorla Maggiore, Italy (46°N, 9°E). The CSO-CW is composed of: (i) grid and sedimentation tank as first flush primary treatment; (ii) four French-type vertical subsurface flow (VF) CW beds as secondary stage (3840 m^2) designed to treat the first flush (up to 640 $l\ s^{-1}$); (iii) a free water surface flow (FWS) wetland with multiple roles of tertiary treatment of first flush and also second flush treatment (3174 m^2), biodiversity increasing, recreational area, and hydraulic buffer (with a floodable surface area up to 7200 m^2). The theoretical hydraulic retention time (HRT) is equal to 36 h.

A sampling campaign has been done in 2014 in order to characterise temporal variations of CSO quality and quantity and to assess CW removal performances. The data about water quantity (CSO flow rates continuously registered by an automatic sensor with a sampling frequency of 15 minutes) are here used as input of the mathematical model.

The mathematical model simulates the unsaturated water flow in VF beds (Richards equation) and the depth of the ponding layer above the VF surface and in the FWS (mass balance equations). In this way, water outflows from each stage of the CW plant are estimated, and the flood mitigation efficiency of the CW is evaluated for different type of CSO events (i.e., single or multiple average CSO events, high return time CSO event).

RESULTS AND DISCUSSION

The model results show the good performance of the CSO-CW as flood mitigation system. The single CSO average event (883 m^3 over 2.4 hours, with a maximum flow rate of 250 l/s) is satisfactorily laminated: (i) the peak flow is reduced by 95%; (ii) the outflow duration is 21 times longer than the one of the CSO event; (iii) the CW is able to store 95% of the influent volume during the CSO event.

The CSO-CW exhibits also performs well for CSO mitigation when a sequence of consecutive CSO average events (up to 5, i.e. the maximum number of consecutive CSO events registered) is considered as shown in Figure 1. In this case, the peak flow is reduced by 53%, the outflow is prolonged 5.7 times compared to the CSO event duration, and 38% of the influent volume is stored during the CSO event.

Flood mitigation performances remain high also for events with high return time (equal to 10 years – maximum flow rate: 3.4 $m^3 s^{-1}$, volume: 11497 m^3, duration: 4.8 h), for which the FWS behaves as a buffer system storing 71% of the influent volume, in addition to the lower (11%) but not negligible mitigation effect provided by the VF beds. Moreover, the peak flow (86% reduction) and the outflow duration (27 times longer than the CSO event duration) are satisfactorily improved for such 10 year return time events.

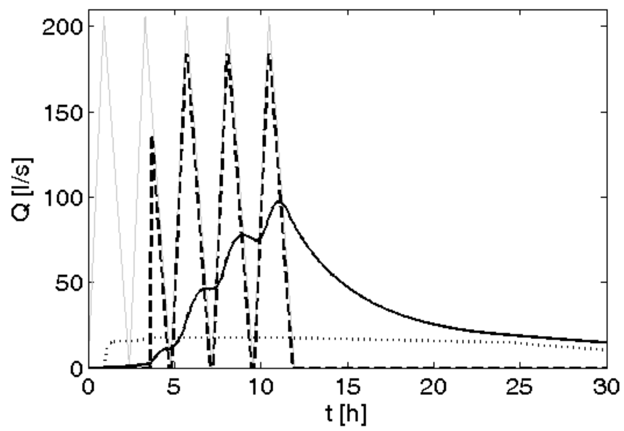

Fig. 1. Influent and simulated effluent flow rate from CSO-CW treatment for a sequence of 5 consecutive CSO mean events: influent CSO (gray line), VF outflow (dotted line), VF overflow (dashed line), and FWS outflow (continuous line).

CONCLUSIONS

The results of this modelling study confirm the potential of CWs to behave as flood mitigation systems providing the additional ecological service of sustainable urban runoff management. The selected case study demonstrates how CSO-CW promotes a shift from a post-development (high peak, short duration) to a pre-development (low peak, high duration) hydrograph influent to the river water body.

REFERENCES

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