Impact of CSOs on agro-urban rural channels through numerical simulations with SWMM model: lesson learnt from an Italian case study

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Highlights

- Experimental monitoring survey.
- Coupled water quality and quality model using SWMM 5.1.
- Interaction between rural and urban areas.

Introduction

During rainfall events, very high flow rates occur in combined sewer systems, which exceed the capacities of wastewater treatment plants (WWTPs): for this reason, a part of the sewage cannot be treated and is directly discharged into receiving water bodies. Combined sewer overflow (CSO) can be a critical inflow source for streams during rainfall events. In northern-Italy, this problem mainly affects the agro-urban context of the metropolitan city of Milan, where the receiving water bodies are often represented by rural channels that are part of a dense and ramified network mainly intended for irrigation and drainage downstream agrarian lands. The continuous release of CSOs in rural channels can increase the risk of a chronic pollution, affecting water used in agricultural and environmental contexts (Masseroni et al., 2018). This study is now developing in the context of *MONAIISa* project, the main objective of which is to increase the awareness about the opportunity of exploiting the self-depuration capacity of rural channels for remediating CSOs in order to preserve quality of water for irrigation and environmental purposes. To pursue this aim, modelling urban drainage system is essential to determine the input flow in rural channels in occasion of rainfall events, so as to simulate flow propagation and pollutants transport through them. A coupled water quantity-quality model is being set up using the Environmental Protection Agency (EPA) Storm Water Management Model (SWMM). Model calibration has been carried out with collecting data obtained during the in-progress monitoring campaign.

Methodology

Case study: Gaggiano sewer system

Gaggiano, municipality located in Milan hinterland, is the specific domain of analysis included in this study (Figure 1): the combined sewerage system of the city drains a catchment area (residential and industrial) of 200 hectares and has an equivalent population about 105’000. The study domain was already under investigation for the impact of CSOs on water quality of rural channels as reported in Ferrario et al. (2021). During rainfall events, CSOs spill directly into the rural channel called *Gamberina*, in which the normal transiting flows vary from a few cubic meters seconds during the winter season up to 1.0-1.5 m^3/s in occasion of the irrigation period. Gamberina channel is separated from Naviglio Grande by six vertical sluice gates: during the irrigation period, a continuous flow rate of 0.9 m^3/s is derived from Naviglio. The connections between the sewer system and the channel are constitute by six CSOs: the studied reach of Gamberina subject to spillways, is about 5 km. In the south of residential and industrial area are collocated two WWTPs: treated water by WWTP2 is then discharged to Gamberina.

Figure 1. Case study domain: sewer network and measuring system collocation.

Monitoring survey

Aim of the present work is to indagate the real CSOs water quality impact on the agricultural network: for this reason, a dense measuring system has been set up (Figure 1). Two measuring and sampling points are placed on the Gamberina channel: both sampling points are equipped with a 24 bottles automatic water sampler integrated with a level gauge each. Sampling starts when water level rises above a defined threshold. Upstream sampler (U) is located at 800 meters downstream the gates and it's distant 200 meters by the downstream sampler (D). 6 rainfall gauges located on the catchment and 11 flow meters in sewer system record continuously. Experimental survey is still in progress: to date, six rainfall events have been recorded (10 February, 11 April, 29 April, 1 May, 24 May and 8 July 2021). Water quality and hydraulic data collected has been employed to perform model calibration.

Model construction

The Storm Water Management Model (SWMM) (Rossman, 2015) is used to build the hydraulic model of Gaggiano urban drainage system: SWMM model has been derived from GIS model. Through *swmmr* package (Leutnant et al., 2019), features relating to size and position of junctions and pipes have been extrapolated from the GIS model. The model framed (Figure 2) divides the area into 1301 sub-catchments, connected with 1355 nodes and 1439 pipes: also, Gamberina canal was designed importing 54 detected cross sections. The model was solicited with measured rainfall at rain gauges: Figure 3 shows the simulated hydrograph in CSO number 416 in occasion of rainfall event of 1 May 2021.

Results and discussion

The model has been calibrated based on collected experimental data. Calibration parameters has been obtained comparing concentration and flow curves registered and simulated in correspondence of downstream sampler and flow meters in sewage system. Despite the results are being processed, the evolution of concentration curves in transition from the upstream to the downstream sampler will allow

Figure 2. Model geometry in SWMM: visualization of the urban drainage system with highlighted CSO number 416.

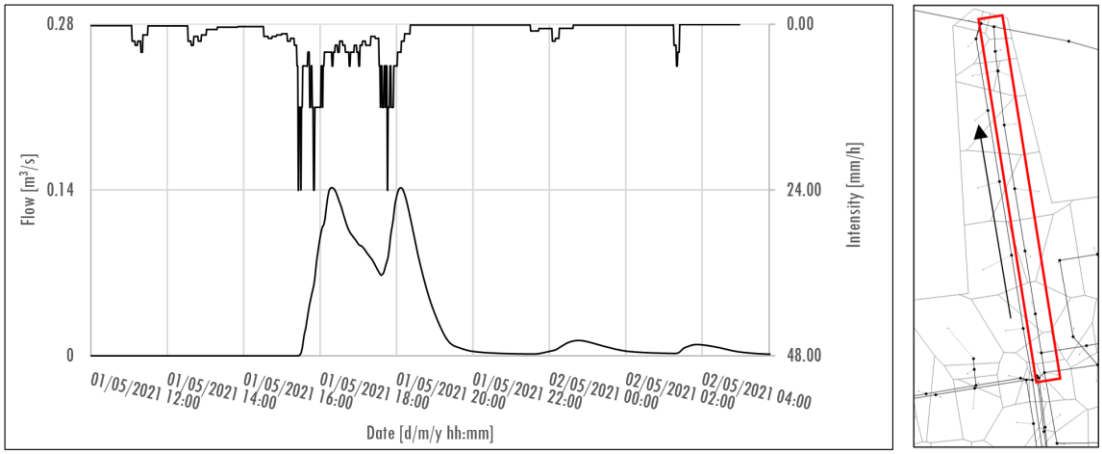

Figure 3. Rainfall measured at P_GAG01 and simulated hydrograph in CSO number 416 for the event of 1 May 2021.

to evaluate the self-depurative capacity of rural network in relation to CSOs.

Conclusions and future work

A coupled water quantity and quality model, calibrated through in-situ measurements, was implemented to assess water flow and pollutant rates in input to the rural channel. Data from experimental surveys were essential for the correct construction of the model, making the modelling tool able to predict how CSOs stress the rural channel during rainfall periods. The use of the calibrated model will permit testing the sustainability of the introduction of alternative solutions for water remediation implemented directly within the rural channel, as proposed in MONAlISa project. This work was developed in the context of the Monalisa project funded by Fondazione Cariplo (grant 2019-2084).

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