Title

Combined sewer overflow characteristics: results of a monitoring campaign on a peri-urban catchment in Italy

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Highlights

- ✓ The quality of Combined Sewer Overflows (CSOs) from urban catchments can alter the quality of environmental resources;
- ✓ The quality of CSOs was investigated during multiple storm events in a real-world urban catchment located in northern Italy;
- ✓ Results show a constant release of pollutants with the discharged runoff, suggesting continuous treatment might be needed for CSO remediation

Introduction

In many regions around the world, the rapid and often poorly controlled development of urban areas is typically followed by the expansion of impervious surfaces such as roads, parking lots and buildings of civil and industrial character, with heavy repercussions on the quality of Combined Sewer Overflows (CSOs) (Ercolani et al. 2018). CSOs are a priority water pollution concern for municipalities served by Combined Sewer Systems (CSSs), since uncontrolled and unmanaged CSOs are often discharged directly in the environment mainly in rural or ephemeral streams or, where feasible, in storage and infiltration ponds. These elements are usually located in peri-urban areas, where the continuous release of untreated water can actively contribute to increasing the risk of acute and chronic pollution of soils, aquifers, and surface waters (Ferrario et al. 2021). Specifically, CSOs can contain significant amounts of anthropogenic pollutants such as chemicals, nutrients, microbials and heavy metals, whose concentrations during CSO events depend on several factors, including (i) the storm severity, duration and pattern, (ii) the size of the urban catchment, (iii) the characteristics of the urban drainage system, (iv) the amount of material accumulated before the storm event (i.e. during the antecedent dry period), (v) the dilution capacity of stormwater runoff during the catchment wash-off process (Barco et al. 2007). Part of these pollutants is usually intercepted by first-flush tanks (FFTs) before reaching the environment. They are storage elements designed to capture and treat few millimetres of the initial storm runoff (called first-flush - FF). However, in urban and peri-urban areas the planning of these mitigation elements is affected by the lack of available spaces, and the implementation of alternative treatment practices is needed (Al Mamun et al. 2020).

In light of these considerations, experimental studies aimed at investigating the time-variability of pollutant loads during CSO events are needed to understand the amount of contaminants discharged within the natural environment. In particular, in this work, the results of a sampling campaign of CSOs discharged from an urban catchment during different storm events are discussed to analyse the shape of the pollution load distribution with the discharged volume and to suggest adequate practices for CSO storage and remediation.

Methodology

Study domain

The study domain is located within an agro-urban area in the north-west of the city of Milan (Fig. 1), specifically, in the municipality of Sedriano (7.7 km^2 in size), characterized by a mix of residential, industrial, commercial and green areas. The urban settlement considered is approximately 1.9 km^2 in size (with a total impervious area of 0.69 km^2) and it is where most of the 12,000 inhabitants of the municipality live (with a density of approximately 1,500 inhabitants per km^2). According to the Köppen classification system (Peel et al. 2007), the area is characterized by a humid subtropical climate, although the last decade has seen an intensification of storm events (precipitations with high intensity and short duration), which have been periodically putting the urban drainage system of the municipality under considerable pressure (Ranzi et al. 2021). The Sedriano urban drainage network, managed by the water and wastewater utility CAP Holding Ltd, is about 23.5 km long and consists of 686 conduits and 651 nodes (mainly manholes). The sewerage is a CSS, designed to collect both sewage and urban stormwater during rainfall events. The flow in the sewerage system is gravity driven. To date, the CSOs are discharged in an

Fig. 1. Study domain: the municipality of Sedriano, in the north-west of the city of Milan (Italy)."

infiltration pond of about 5.000 m^3 located at the outlet of the urban catchment in an open rural area close to cultivated lands and irrigation canals.

Hydro-meteorological monitoring

The spillway of the drainage network was monitored in continuous from January 2021 through an area-velocity flow meter with a time resolution of 2 minutes. Rainfall data was collected from the year 2019 (with a time resolution of 10 minutes) at two rain gauges located inside the study domain, approximately 1.5 km from the catchment outlet.

Water quality measures

An automatic water sampler equipped with 24 bottles was installed at the CSS spillway in January 2021 (monitoring activity still in progress) with the aim to study the water quality during each CSO event across seasons. The sampler was integrated with a float so that the sampling would only take place when CSOs are trigged. The sampling procedure consisted in three steps: the first eight bottles were filled every 2 minutes the second eight every 5 minutes and the last eight every 10 minutes, the goal here being to gain considerable insight on the water quality at the beginning of the overflow. Each bottle was filled with 250 ml of discharged water, and the canister was delivered to the labs within 4 h from collection. Within a larger project, chemical-physical characteristics of the water samples such as Biological and Chemical Oxygen Demands (BOD and COD, respectively), total suspended solids, nutrients and heavy metals, were evaluated based on different ISO protocols. However, in the present work, only COD and heavy metals (aluminium, iron, copper and zinc) were chosen to characterize the level of inorganic pollution (Barco et al. 2007).

Results and discussion

Four storm events of different magnitude were recorded at the study site between February and July 2021 and their characteristics are reported in Tab. 1. The maximum rainfall intensity of the storm events ranged from about 9 to 56 mm/h, with a duration between 95 and 120 minutes and depth between 8 and 12 mm. Dry periods lasted from about few hours to 27 days, whereas the recorded CSO volume was between 980 m^3 to 2100 m^3 with maximum flow rate ranging from 470 to 2000 l/s. The time lag between the precipitation peak and CSO peak ranged from 25 to 45 minutes.

Tab 1. Main characteristics of the storms recorded between February and July 2021 at the study site (Sedriano, north of Italy).

Event no.	Date	Rainfall duration [min]	Rainfall depth [mm]	Max rainfall intensity [mm/h]	CSO volume [m^3]	Max flow rate [l/s]	Time lag [min]	Dry period [day]	Collected samples
1	Feb 10th	120	8.7	9.6	981	476	40	2.9	9
2	May 1st	110	7.9	25.1	1133	848	35	17.1	6
3	Jul 4th	105	14.6	56.4	4754	2175	25	27.0	4
4	Jul 8th	95	12.2	31.1	2749	1318	25	0.86	7

The quality of CSOs during each storm event is reported in Fig. 2, where the normalized cumulative mass of COD and heavy metals (aluminium, iron, copper and zinc) is plotted against the CSO cumulative volume for the four events presented in Tab.1. In all cases, the slope of the mass emission line is very close to 45 degrees for each quality parameter, with a little deviation above the diagonal in the storm event of May 1st, where a slight FF occurs especially for the COD parameter. In contrast, on July 8th a little deviation below the diagonal is found for COD and zinc in the last part of CSO event. This behaviour might be related to the short dry period which preceded the rainfall event of July 8th, which probably completed the catchment wash-off started with the previous rainfall event.

Moreover, in all cases, the results are far from the Bertrand-Krajewski (1998) definition of FF, where at least the 80% of pollutant mass is discharged in the first 30% of runoff volume. In our case, the release of pollutant mass appears to be largely consistent with the release of the discharged volumes during CSO events. Despite the analysis being based on a limited number of storm events with significant differences in terms of discharged flows and volumes, rainfall depths and dry periods, these results suggest that continuous treatment solutions might be good CSO remediation practices.

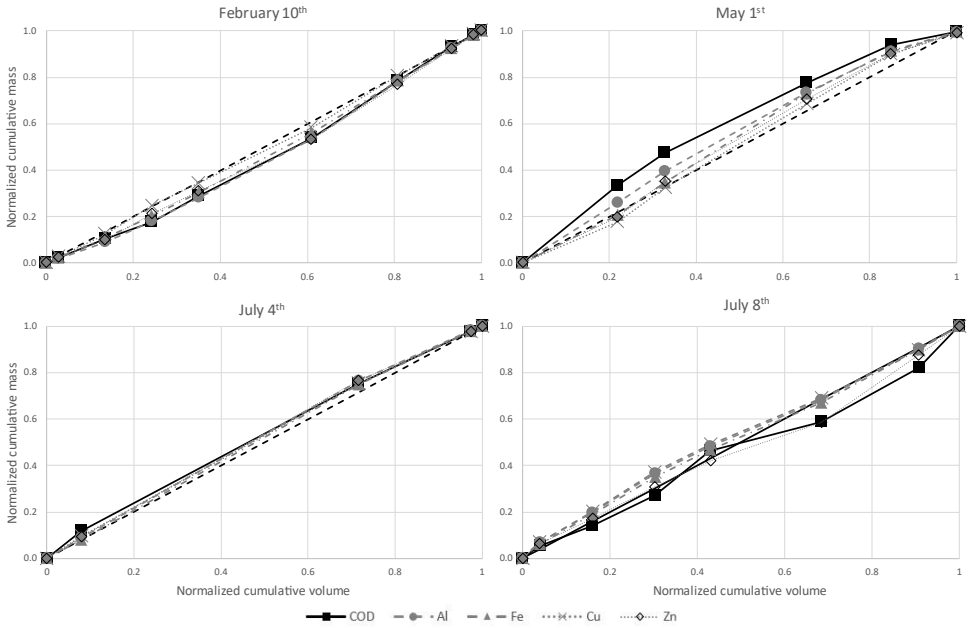

Figure 2. Normalized mass of pollutants (COD, Al-aluminium, Fe – iron, Cu – copper, Zn – zinc) vs. normalized discharged runoff volume.

Conclusion

In this work, CSOs from the CSS spillway of a urban catchment located in the metropolitan city of Milan were monitored to investigate the CSO quality pattern during four storm events with different characteristics. The hydrograph and pollutograph of COD and four heavy metals were analysed for each event, by studying the normalized cumulative mass vs. the normalized cumulative runoff volume. The results show that the release of pollutant mass is largely consistent with the release of the discharged runoff volumes in all CSO events except one (May 1st) when a slight FF behaviour could be seen for the COD parameter. Although the monitoring activity is still ongoing, these preliminary findings can help municipalities and water managers identify suitable CSO remediation practices, which, for this case study, would seem to be oriented towards continuous treatments.

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