Assessing the contribution of wet-weather discharges on micropollutants release by urban catchments

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INTRODUCTION

Wet-weather discharges from integrated urban wastewater systems (IUWS) represent a threat for surface waters. When the system capacity is reached during medium/large rain events, a mixture of stormwater and untreated wastewater is discharged to surface water through Combined Sewer Overflows (CSOs) or Bypass (BP) of Wastewater Treatment Plants (WWTP). The loads of contaminants discharged by CSOs and BP are highly variable in time and space (Petrie, 2021), making it difficult to correctly monitor and assess the environmental risk for a specific catchment. The present work aims at assessing the impact of 12 micropollutants present in wet-weather discharges on receiving surface water, by using an archetype IUWS, defined through a stochastic approach. Monitoring data from literature were retrieved and elaborated to characterize the discharges and to predict the risk posed by micropollutants on a yearly horizon. The calculated risk from wet-weather discharges was compared against that posed by WWTP effluent (EFF).

MATERIALS AND METHODS

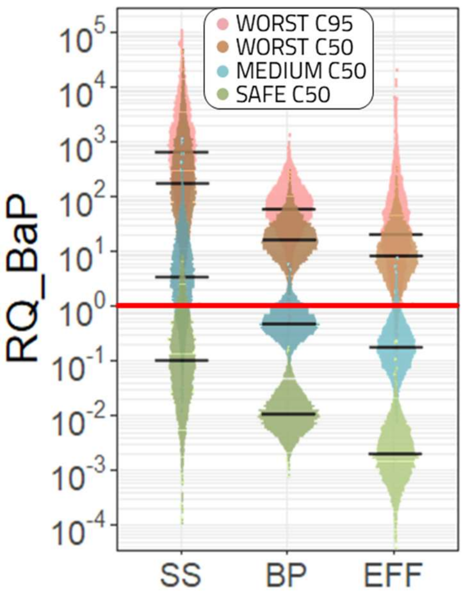
An archetype IUWS was defined, consisting of three discharge types (several CSOs discharges, one BP of the WWTP, and the EFF) and a river as receiving surface water. All these *i-th* elements (CSOs, BP, EFF, River) of the IUWS were characterized in terms of both water quantity (discharged volume, V_i, and river flowrate, Q_R) and quality (concentrations of *j-th* micropollutants: $C_{i,j}$).
Data gathered from literature were used to estimate probability distributions for each variable of the literature IUWSs (V_i, Q_R and $C_{i,j}$). Various percentiles were extracted from these probability distributions to realize the parameterization of the archetype IUWS variables and to identify six scenarios, representing different pollution levels in the discharges through Concentration Percentiles (CP scenarios: using distributions for the 50th, 75th, 95th percentiles (C50, C75, C95) of the concentration distributions) and different dilution levels in the river (DF scenarios: using distributions of Dilution Factors for Safe, Medium, and Worst case of dilution).
The chronic risk was assessed for each micropollutant in each scenario through Risk Quotients (RQ) calculated using annual loads and the uncertainty analysis procedure. RQs were calculated for the river as risk posed by single micropollutants in each discharge ($RQ_{i,j}$), by all micropollutants in one *i-th* discharge (RQ_i), and by single *j-th* micropollutants in all discharges (RQ_j).

RESULTS

C and RQ percentiles values are usually arbitrarily chosen for risk assessment procedures, leading to highly different results depending on the selected percentiles. Conversely, different choices of non-default dilution factor, allows to represent hydraulic conditions across different IUWS, and to evaluate the climate change impact that may result in lower dilution of the discharges.
We found that the choice of different percentiles of the pollutant concentration did not determine high

differences in the RQ values, while the choice of DF can impact the outcome of the risk assessment. For example, for Benzo(a)Pyrene (BaP, Figure 1a) median RQ values were found to be less than 10 times higher from C50 to C95, while values are up to 10,000 times higher from Safe to Worst scenario. Therefore, an accurate risk assessment requires to correctly quantify the hydraulic variables of the IUWS (and specifically the dilution factor), as neglecting the impact of dilution and assessing only the discharged concentrations might lead to significant overestimation of the environmental risk. As to micropollutants exceeding the threshold of RQ=1 ($n_{RQi,j>1}$) in Figure 1b, the higher risk is posed by Polycyclic Aromatic Hydrocarbons (PAH), with BaP as the most relevant. Pharmaceuticals (PHARM) represent the second class of concern for the recipient, being EFF the main source, while wet-weather discharges contribute to the risk only in the Worst scenario. The third class of concern is Heavy Metals (HM), whith high risk in Worst scenario in relation to CSOs. Pesticides (PEST) pose the smallest risk to the river both in Medium and Worst scenario, with Diuron being the most critical compound.
Overall, wet-weather discharges pose a considerable high risk to the river for PHARM and HM only in the Worst scenario. This suggests that, in situations of surface water scarcity and in consideration of climate change effects, research on these two classes of contaminants in wet-weather discharges is needed to assess their release in the environment and identify appropriate interventions.

(a)



(b)

SCENARIOS DF	CP	RQP	CSOs $n_{RQ_{i,j}>1}$	BP	EFF
SAFE	C50	RQ50	0	0	0
SAFE	C50	RQ75	0	0	0
SAFE	C50	RQ95	1 PAH	0	0
SAFE	C75	RQ50	0	0	0
SAFE	C75	RQ75	0	0	0
SAFE	C75	RQ95	1 PAH	0	0
SAFE	C95	RQ50	0	0	0
SAFE	C95	RQ75	1 PAH	0	0
SAFE	C95	RQ95	1 PAH	0	0
MEDIUM	C50	RQ50	1 PAH	0	0
MEDIUM	C50	RQ75	2 PAH	0	1 PHARM
MEDIUM	C50	RQ95	3 PAH 1 HM	1 PAH	3 PHARM
MEDIUM	C75	RQ50	1 PAH	0	0
MEDIUM	C75	RQ75	2 PAH	1 PAH	1 PHARM
MEDIUM	C75	RQ95	3 PAH 1 PHARM 2 HM 1 PEST	1 PAH	3 PHARM 1 PAH
MEDIUM	C95	RQ50	2 PAH	1 PAH	0
MEDIUM	C95	RQ75	3 PAH 1 HM	1 PAH	2 PHARM
MEDIUM	C95	RQ95	3 PAH 2 PHARM 2 HM 2 PEST	1 PAH	1 PAH 3 PHARM
WORST	C50	RQ50	3 PAH 2 PHARM 2 HM 2 PEST	3 PAH	3 PAH 3 PHARM 1 HM 1 PEST
WORST	C50	RQ75	ALL	3 PAH 1 PHARM	ALL
WORST	C50	RQ95	ALL	3 PAH 3 PHARM 1 HM	ALL
WORST	C75	RQ50	3 PAH 3 PHARM 3 HM 2 PEST	3 PAH	3 PAH 3 PHARM 1 HM 3 PEST
WORST	C75	RQ75	ALL	3 PAH 2 PHARM 1 HM	ALL
WORST	C75	RQ95	ALL	3 PAH 3 PHARM 1 HM	ALL
WORST	C95	RQ50	3 PAH 3 PHARM 3 HM 2 PEST	3 PAH 2 PHARM 1 HM	3 PAH 3 PHARM 2 HM 3 PEST
WORST	C95	RQ75	ALL	3 PAH 2 PHARM 1 HM	ALL
WORST	C95	RQ95	ALL	3 PAH 3 PHARM 1 HM 1 PEST	ALL

Figure 1. (a) $RQ_{i,j}$ for BaP due to single discharges. (b) Number of exceedances of the threshold (RQ=1) for each discharge in each scenario, per micropollutant class. Colours from green to red represents higher $n_{RQi,j>1}$.

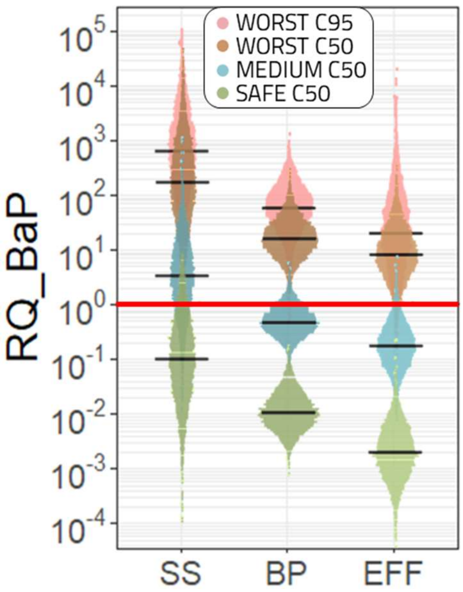
CONCLUSIONS

This study provides a useful tool for decision makers in evaluating the contribution of wastewater discharges on affecting the aquatic ecosystem in a long-term perspective, through the assessment of chronic risk, also identifying the most critical micropollutants. Our approach allows for a prioritization of discharges and micropollutants in the present situation and also in a climate change perspective, addressing the best mitigation actions which should be implemented to maintain the risk at acceptable levels.

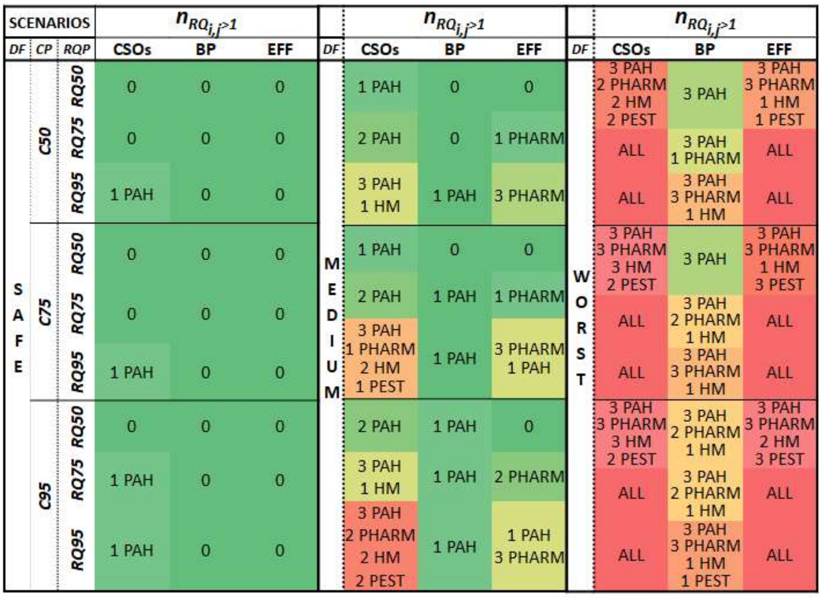
REFERENCES

Petrie, B., 2021. A review of combined sewer overflows as a source of wastewater-derived emerging contaminants in the environment and their management. *Environ. Sci. Pollut. Res.* 28, 32095–32110.

(a)



(b)



SCENARIOS		SAFE $n_{RQi,j>1}$			MEDIUM $n_{RQi,j>1}$			WORST $n_{RQi,j>1}$		
CP	RQP	CSOs	BP	EFF	CSOs	BP	EFF	CSOs	BP	EFF
C50	RQ50	0	0	0	1 PAH	0	0	3 PAH 2 PHARM 2 HM 2 PEST	3 PAH	3 PAH 3 PHARM 1 HM 1 PEST
C50	RQ75	0	0	0	2 PAH	0	1 PHARM	ALL	3 PAH 1 PHARM	ALL
C50	RQ95	1 PAH	0	0	3 PAH 1 HM	1 PAH	3 PHARM	ALL	3 PAH 3 PHARM 1 HM	ALL
C75	RQ50	0	0	0	1 PAH	0	0	3 PAH 3 PHARM 3 HM 2 PEST	3 PAH	3 PAH 3 PHARM 1 HM 3 PEST
C75	RQ75	0	0	0	2 PAH	1 PAH	1 PHARM	ALL	3 PAH 2 PHARM 1 HM	ALL
C75	RQ95	1 PAH	0	0	3 PAH 1 PHARM 2 HM 1 PEST	1 PAH	3 PHARM 1 PAH	ALL	3 PAH 3 PHARM 1 HM	ALL
C95	RQ50	0	0	0	2 PAH	1 PAH	0	3 PAH 3 PHARM 3 HM 2 PEST	3 PAH 2 PHARM 1 HM	3 PAH 3 PHARM 2 HM 3 PEST
C95	RQ75	1 PAH	0	0	3 PAH 1 HM	1 PAH	2 PHARM	ALL	3 PAH 2 PHARM 1 HM	ALL
C95	RQ95	1 PAH	0	0	3 PAH 2 PHARM 2 HM 2 PEST	1 PAH	1 PAH 3 PHARM	ALL	3 PAH 3 PHARM 1 HM 1 PEST	ALL

Figure 1. (a) $RQ_{i,j}$ for BaP due to single discharges. (b) Number of exceedances of the threshold (RQ=1) for each discharge in each scenario, per micropollutant class. Colours from green to red represents higher $n_{RQi,j>1}$.