Predicting long-term pharmaceutical concentrations during sewer overflows using a census data driven model

R. Delli Compagni *, F. Blumensaat **, A. Turolla*, M. Antonelli*, C. Ort**

* Department of Civil and Environmetal Engineering (DICA), Politecnico di Milano, 20133 Milan, Italy.
* E-mail address: riccardo.dellicompagni@polimi.it, andreaturolla@polimi.it, manuelaantonelli@polimi.it
** Eawag, Swiss Federal Institute of Aquatic Science and Technology, 8600 Dübendorf, Switzerland.
** E-mail address: frank.blumensaat@eawag.ch, christoph.ort@eawag.ch

Abstract: A new modelling framework, which combines census and georeferenced data with a mechanistic storm water model, was developed to predict concentration dynamics of pharmaceuticals (PhACs) during overflow events. The model was verified with measurements and used to perform a long-term (1 year) risk assessment in a small urban catchment in Switzerland. Results show that census and georeferenced data are useful information that can be used as new type of model inputs to correctly predict PhACs concentration during combined sewer overflow (CSO) events.

Keywords: pollutant load, river quality, modelling, combined sewer overflow, census data, risk assessment

Introduction

As a result of combined sewer overflows (CSO), pharmaceutical drugs (PhACs) are frequently discharged to surface water bodies after rain events (Musolff *et al*., 2010, Phillips *et al*., 2012). Due to potentially high temporal fluctuations of PhACs (Ort *et al*., 2005), peak concentrations can exceed acute environmental quality standards, posing a risk to aquatic organisms. Assessing compliance with standards would require numerous high-frequency monitoring campaigns, making sampling economically not feasible on a regular basis for thousands of CSO sites in a country.

Therefore, models may be used to indicate where and what kind of fluctuations we would expect to optimise sampling campaigns and perform risk assessment although the prediction of realistic exposure scenarios at high temporal resolution is highly challenging. One reason is due to the lack of unknown and/or confidential information (e.g., location of the person taking a certain drug, drug dosage, excretion time, etc.,) which would provide optimal inputs for in-sewer mechanistic models.

However, other types of information (e.g., total number of prescribed drugs, household location, average age and sex of the population, etc.,) are generally made available with different levels of aggregation (e.g., national, district, canton, neighbourhood, etc.,) in census database and may be a valuable alternative to the above-mentioned types of model inputs.

The aim of this work was to combine new type of data with a complex hydrodynamic model to: i) setup a census data driven model to realistically simulate overflows and PhACs concentrations, ii) assess the risk of PhACs discharges on river water quality during rain events over a long-term period (1 year).

Material and Methods

Data collection

Figure 1 shows the study area where a calibrated hydrodynamic model is available. Census data (n° of people per household, age and sex of the population) at different aggregation levels were retrieved from the Swiss Federal Statistical online database (STAT-TAB); local drug consumption data (n° of people taking a certain drug) were collected from a public health report prepared by Helsana (Schneider *et al*., 2018). Drug-specific information (e.g., Defined Daily Dose - DDD, excretion rate), was retrieved from the WHO Collaborating Center for Drug Statistics Methodology (WHO, 2009). Local drinking water consumption data were provided by the local utility. From the CSO location, real measurements (sampling frequency dt=5 min, pooled to 20-minute composite samples) were used for model plausibility checks. Precipitation data was available from a nearby rain gauge and house locations were obtained from open street map.

Model set-up

Each house was modelled as a point source composed of a defined number of people (healthy and sick), of a defined age and sex, who discharge their wastewater flow and PhAC load to the closest sewer manhole (see detail in Figure 1). PhAC load dynamics were estimated using a modified version of the Sewage Pattern Generator (SPG, 2013) to include information such as population age and sex, DDD and drug excretion rate; wastewater flow was calculated as the product of the number of people and an average daily drinking water consumption in this area (160 L s^{-1}). A typical diurnal pattern for drinking water demand (Candelieri and Archetti, 2014) was applied to reproduce the actual dry weather flow variability. Rain data, wastewater flow and PhAC loads were used as inputs to the hydrodynamic model to estimate number of overflows and PhAC concentrations at the CSO location.

Model performances evaluation

Input model variability (e.g., associated to age and sex of people) and uncertainty (e.g. associated to drug-specific information, such as DDD and excretion rate) was propagated to model output by running multiple simulations. Results were compared with real measurements and a pattern recognition algorithm was performed to identify similar PhAC concentration pattern.

Long term risk assessment

The model was run over a long-term period (1 year) and a time series analysis performed. In particular, three indicators were evaluated: i) frequency of exceedance above the standards, ii) duration of exceedance above the standards and, iii) extent of the exceedance.

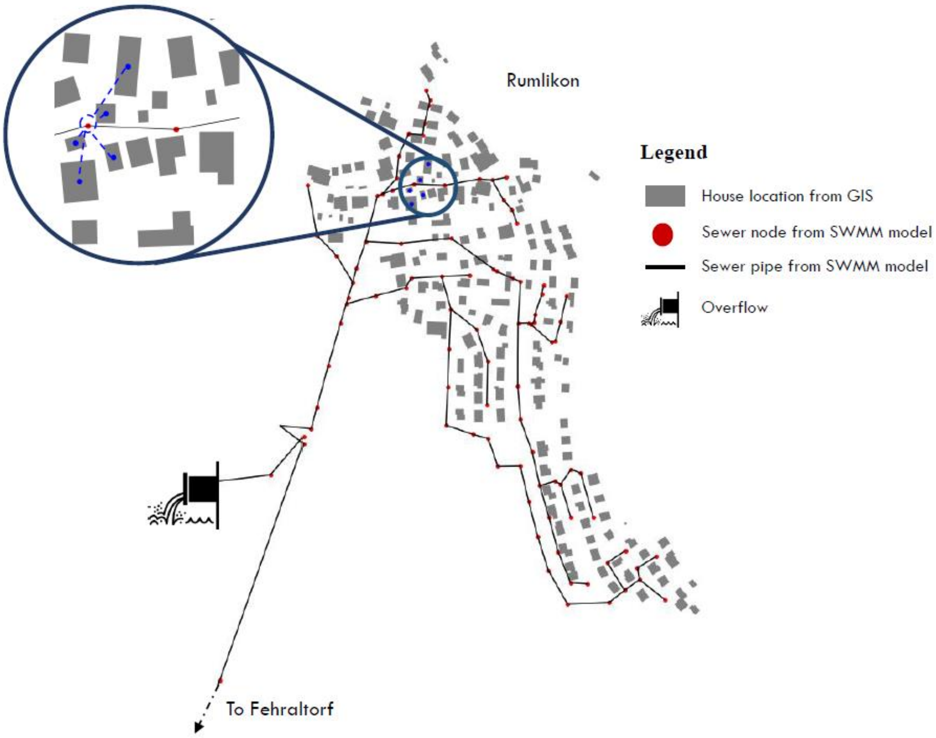

Figure 1 Study area.

Results and Discussion

Model performances evaluation

Preliminary results show that estimated wastewater flow was around 2 L s^{-1} ± 0.5, showing good agreements with flow measurements. During short rain events (< 1 hour), measured PhACs concentrations were within model uncertainties, confirming model reliability in making predictions.

Risk assessment

Preliminary results (Figure 2) show that during CSOs diclofenac concentrations exceed the standard (0.05 µg L^{-1}) with a duration that can vary from 1 to 11 hours with a corresponding frequency of approximately 100 and 20 times. Up-to-date, acute standard for diclofenac is not available and the chronic one was used for the analysis.

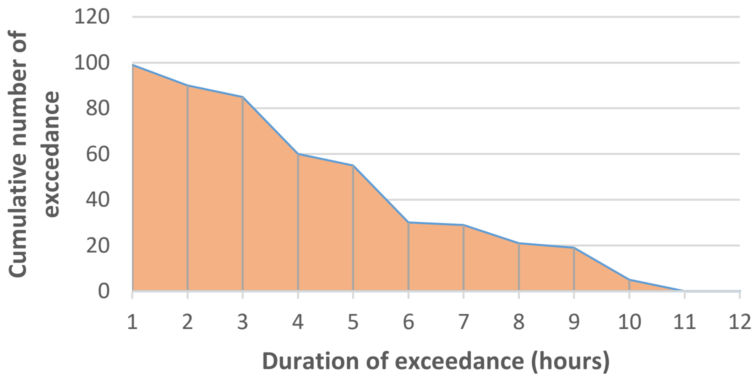

Figure 2 Cumulative concentration-duration-frequency curve for diclofenac during CSO.

Expected results will show which levels of aggregation (e.g, national or local, house-specific or catchment-specific, etc.,) for this new type of model inputs is required to estimate correctly flow and PhACs concentration fluctuations; moreover, a long-term risk assessment will be performed for a large set of PhACs.

Conclusions

We conclude that census and geo-referenced data are suitable model inputs to detail hydrodynamic model in order to simulate overflows and PhAC load dynamics. Moreover, the developed framework can be used to optimise sampling campaigns and perform risk assessment for a broad range of PhACs.

References

Candelieri, A. and Archetti, F. (2014) Identify typical urban water demand pattern for a reliable short-term forecasting – The icewater project approach. Procedia Engineering, **89**, 1004–1012.

Musolff A., Leschik S., Reinstorf F., Strauch G., Schirmer M. (2010) Micropollutant loads in the urban water cycle. *Environ. Sci. Technol.*, **44,** 4877–4883.

Ort C., Schaffner C., Giger W., Gujer W. (2005) Modeling stochastic load variations in sewer systems. *Water Science and Technology*, **52** (5), 113-122.

Phillips P.J., Chalmers A.T., Gray J.L. , Kolpin D.W. , Foreman W.T., Wall G.R. (2012) Combined sewer overflows: an environmental source of hormones and wastewater micropollutants. *Environ. Sci. Technol.*, **46**, 5336–5343.

Schneider R., Schur N., Reinau D., Gut S., Schwenkglenks M., Meier R. C. (2018) *Helsana-Arzneimittelreport für die Schweiz,* Report, Basel, Switzerland.

SPG 2013. Sewage Pattern Generator software available from Eawag http://www. eawag.ch/en/department/sww/software/ Accessed: on March, 2019.

STAT-TAB.https://www.bfs.admin.ch/bfs/en/home/services/recherche/stat-tab-online-data-search.html. Accessed on March, 2019.

WHO Collaborating Centre for Drug Statistics Methodology, Oslo, Norway. https://www.whocc.no/ddd/definition_and_general_considera/. Accessed on March, 2019.