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Future challenges for urban drainage systems regarding combined sewer overflow emissions

Défis futurs pour les systèmes d'assainissement urbain concernant les émissions de rejets des déversoirs d'orage

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RÉSUMÉ

Les systèmes de drainage urbain doivent s'adapter aux défis futurs liés au changement climatique et à la croissance urbaine. L'augmentation de l'intensité et de la fréquence des précipitations extrêmes et des périodes sèches prolongées, combinée à l'urbanisation induite par l'imperméabilisation des surfaces, affecte le ruissellement de surface, les fréquences, les volumes et les concentrations d'émissions des débordements d'égouts unitaires (CSO), ainsi que les risques d'inondation. Contrairement à la directive autrichienne relative à la conception des déversoirs d'orage, qui définit une efficacité minimale basée sur les caractéristiques des précipitations ($r_{720,1}$), la directive révisée sur le traitement des eaux urbaines résiduaires proposée par la Commission européenne exige que les déversoirs d'orage représentent moins de 1 % de la charge annuelle d'eaux urbaines résiduaires collectées. Cette étude analyse le système de drainage de la ville d'Innsbruck. Les émissions de CSO sont prédites à l'aide d'un modèle conceptuel. Sur la base du modèle, les deux directives différentes sont comparées dans le cadre de différents scénarios climatiques futurs, y compris les changements dans les modèles de précipitations et le nombre de zones découplées. Les résultats permettront de mieux comprendre les changements dans la concentration des émissions et l'efficacité du système dans le cadre des scénarios de changement climatique futur et en ce qui concerne les différentes directives.

ABSTRACT

Urban drainage systems must adapt to future challenges driven by climate change and urban growth. Increasing intensity and frequency of extreme precipitation events and prolonged dry periods in combination with surface sealing-driven urbanisation affect surface runoff, combined sewer overflow (CSO) frequencies, volumes and emission concentrations as well as flood hazard. While extreme precipitation events are more relevant for flood hazards, smaller precipitation events are more relevant for emission concentrations in CSOs. In contrast to the Austrian directive for the design of CSOs, defining a minimum efficiency based on rainfall characteristics ($r_{720,1}$), the revised urban wastewater treatment directive proposed by the European Commission demands a stormwater overflow of less than 1% of the annual collected urban wastewater load. This study analysis the drainage system of the city of Innsbruck, located in the western Austrian Alps. The CSO emissions are predicted using a conceptual model and a simulation period of more than 10 years. Based on the model, the two different directives are compared under different future climate scenarios, including changes in precipitation patterns and number of decoupled areas. Results will develop a better understanding of changes in emission concentration and the efficiency of the system under future climate change scenarios and with regard to the different directives.

KEYWORDS

Climate Change Impacts, Climate Extremes, Combined Sewer Overflow Emissions, European Union Directive, Stormwater Runoff

1 INTRODUCTION

Drainage systems were originally introduced as a part of our cities' infrastructure to collect and convey storm- and wastewater out of urban areas (Chocat et al., 2007). With the consequences climate change poses (IPCC, 2022), namely more frequent and extreme precipitation events, heatwaves and prolonged dry periods, urban stormwater management is increasingly challenging. Apart from preventing and reducing pluvial flooding, urban drainage systems must ensure acceptable water qualities in Combined Sewer Overflows (CSO) to reduce pollution in nearby receiving water bodies. Surface-sealing driven urbanisation impedes or prevents infiltration and, thus, results in an increase in surface runoff. In terms of flood hazard reduction, additional storage volume can be generated by emptying sewer pipes and storage basins prior to precipitation events. However, this contradicts the reduction of water pollutant by maintaining a particular water level in the pipes and reducing CSO frequency. Those two contrary approaches are one of the major future challenges in stormwater management in terms of climate change adaptation.

The Austrian guideline for the design of CSOs "*guideline 19*" (ÖWAV-RB 19, 2007) described by Kleidorfer and Rauch (2011) defines a minimum efficiency for dissolved substances in combined sewer systems. This ensures 40 to 60 % of the annual stormwater discharge to reach the biological treatment of the wastewater treatment plant. Overflows caused by stronger precipitation events are drained into the nearby receiving water body via CSOs. This leads to discharge of diluted but untreated sewage and, in addition to stormwater discharge in separated sewer systems, represents relevant emission points for solids in urban drainage. Considering the minimum values, approximately 1 to 3 % of the annual polluted load transported in the network are discharged via CSOs. This proportion can be higher in case of remobilisation of deposits. According to *guideline 19*, the efficiency of a system is calculated based on a long-term simulation of at least 10 years. The required efficiency is calculated based on the rain characteristic $r_{720,1}$ (average precipitation in 12 hours (=720 min) with a return period of 1 year in mm/12h calculated from a long-term series of minimum 10 years). Areas with higher $r_{720,1}$ values allow higher emissions.

Recently, a revised urban wastewater treatment directive was proposed by the European Commission (European Commission, 2022). This proposal defines the following directive, which is different to the guidelines in the present version of *guideline 19* in Austria. Thereby, stormwater overflow must not represent more than 1% of the annual collected urban wastewater load calculated in dry weather conditions and a progressive elimination of untreated discharges of urban runoff through separated systems, unless it can be demonstrated that those discharges do not cause adverse impacts on the quality of receiving waters (European Commission, 2022).

The aim of this study is to analyse the impact of climate change on urban drainage systems, with focus on CSO emissions, frequencies and volumes, under consideration of the present Austrian directive (*guideline 19*) and the newly proposed European directive.

2 METHODS

2.1 Case study - Innsbruck

Innsbruck is the capital of Tyrol located at 574 m.a.s.l. in western Austria. The alpine city is situated at 47°16' N and 11°24' E in the Inn valley. Innsbruck comprises an area of approximately 104,9 km² and 131.059 inhabitants (Government Tyrol, 2022).

The sewer system is, apart from a few exceptions, a combined system, like most Austrian cities. The 14 surrounding municipalities are connected to the sewer system of Innsbruck, with wastewater mainly directed to the wastewater treatment plant located in the eastern part of Innsbruck. The wastewater treatment plant is designed for 400.000 inhabitants and includes a chemical, biological and mechanical treatment. The pipe length of the sewer network managed by the "Innsbrucker Kommunalbetriebe" is approximately 257 km long (IKB, 2022). Decoupled areas are considered using a constant factor of 10%, excluding the oldtown area and "Mentelberg", as these areas do not include infiltration systems. Since 2002 stormwater connection of new stormwater inflows into the combined sewer system is prohibited and stormwater must be treated on-site.

2.2 Models

2.2.1 Regional Climate Projections

In order to consider the effects of changing precipitation patterns driven by climate change, we used an improved statistical downscaling procedure, initially introduced in Kleidorfer et al. (2015), to derive climate change signals of extreme sub-daily precipitation from Regional Climate Model (RCM) simulations. Based on statistical extreme precipitation heights with return periods up to 100 years, relative changes were determined as ratio between the near future and the reference period (1971-2000), differentiated by the event duration.

2.2.2 Conceptual model

The software KAREN (Dotto et al., 2011), including a conceptual model, is used to predict the combined sewer overflow conditions. KAREN is a very simple and fast software to predict and simulate emission rates for combined sewer systems. The model (Fig. 1) involves different catchments that belong to the drainage network of Innsbruck and considers losses (initial loss and permanent loss), effective impervious areas, flow time, dry weather runoff, volume of the combined sewer overflow, throttle capacity and sedimentation efficiency. The simulation is done for a 10 year period of precipitation (Kleidorfer and Rauch, 2011). Surrounding municipalities, which drain into the system of Innsbruck, are included through a constant inflow.

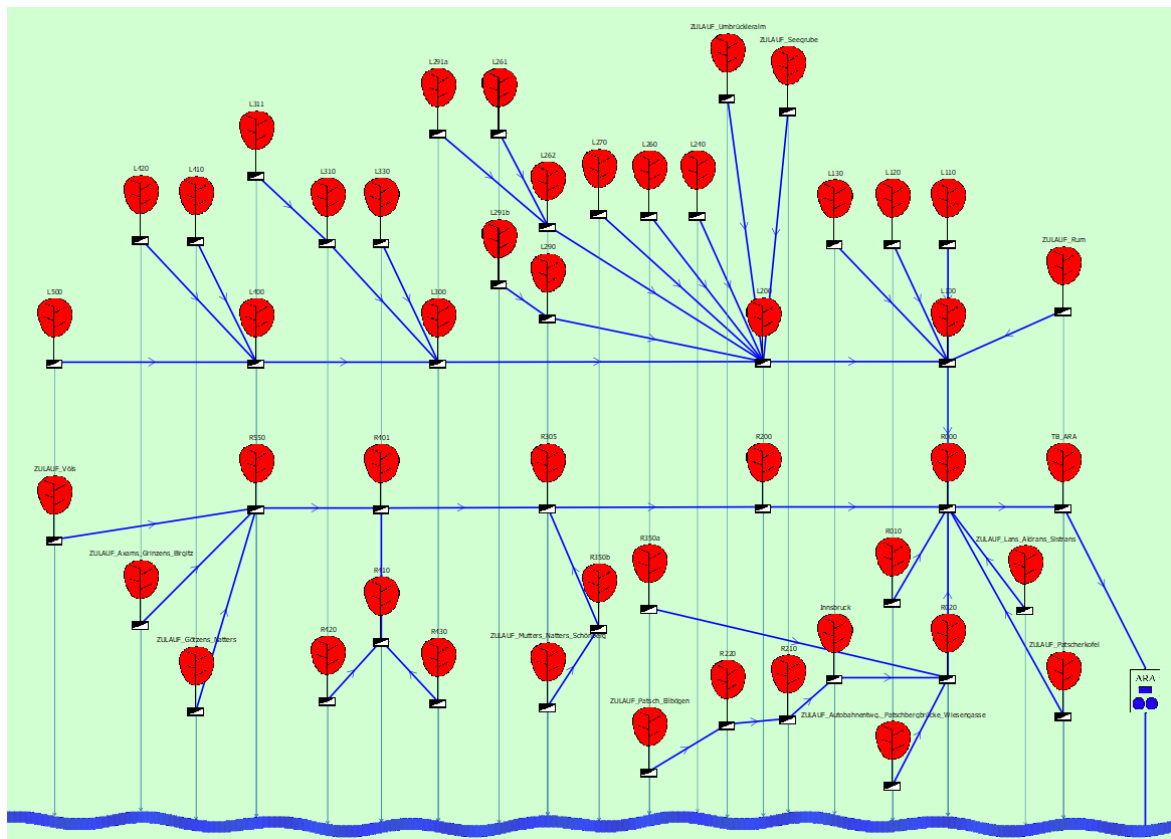


Figure 1. Example of the conceptual model in KAREN.

The conceptual model is used to analyse the requirements according to current and future directive (*guideline 19* and the new proposal of the urban wastewater treatment directive). Therefore frequency and loads of CSO emissions will be calculated for the current situation and future scenarios. Future scenarios will consider changes in precipitation patterns caused by climate change (intensity of events, changes in dry-weather periods) and changes in land-use caused by increase or decoupling (decentralised stormwater management) of impervious areas.

3 RESULTS

The aim of this study is to analyse the differences according to the use of the two directives and the consequences of climate change on the change of emissions, frequency and quantity of CSOs.

4 ACKNOWLEDGEMENT

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