Influence of discharge and temperature on the transport of tracer pollutants along an urban river (Zenne, Belgium)

Influence du débit et de la température sur le transport de polluants traceurs le long d'une rivière urbaine (la Zenne, Belgique)

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RÉSUMÉ

Les activités humaines ont profondément modifié la circulation naturelle et la qualité de l'eau des rivières menant à des risques hydrologiques et dangers chimiques accrus. Un exemple extrême de rivière fortement modifiée est la Zenne à Bruxelles. Dans et autour de la ville, la rivière définit un petit corridor fluvial (800 km²) d'une grande diversité d'occupation du sol : agriculture intensive en amont, urbanisation dense au centre et pression industrielle en aval. Dans ce contexte nous avons établi une représentation box-model de bilans de masse pour une sélection de polluants-traceurs (N et P, demande biologique en oxygène, une sélection de métaux, pesticides et HAP) pour différentes gammes de débits et de températures. Pour cela, nous avons établi la distribution des débits, températures et concentrations en polluants aux frontières du système, y compris pour les rejets des stations d'épuration et des industries, à partir de bases de données institutionnelles. Nous discutons les bilans de masses des polluants traceurs pour des situations moyennes annuelles, pour des conditions de temps sec et pluvieux, et pour des hautes et basses températures de manière à comprendre l'influence du climat sur le transport/transfert et la rétention de polluants dans une rivière fortement impactée par l'activité humaine. Les résultats de cette étude ont été obtenus dans le cadre du projet de recherche OSIRIS (INNOVIRIS Anticipate 2015-2018).

ABSTRACT

Human activities profoundly modified natural water circulation as well as water quality of rivers, with increased hydrological risks and chemical hazards as consequence. An extreme example of strongly modified river system is the river Zenne crossing the city of Brussels. In and around the city, the river determines a small vertical urbanized area (800 km²) combining extreme land-use landscapes: intensive agricultural activities upstream, a dense cityscape including a forested area in the center, and a strong industrial influence downstream. In this context, we established a box-model representation of selected polluting chemicals mass budgets (N and P, biological oxygen demand, and a selection of metals, pesticides and PAHs) for variable discharge and temperature ranges. For this, we have assessed the distribution of water flows, and pollutant tracer concentrations at the boundaries of the studied water system, including wastewater treatment plants and industrial waters, from available institutional databases. We discuss pollution tracer budgets for a yearly average situation, for dry and wet, and for warm and wintry weather conditions in order to understand climate effects on the transport/transfer/retention of pollutants in a highly human-impacted modified stream. Results from this study were obtained in the framework of the OSIRIS research project (INNOVIRIS Anticipate 2015-2018).

KEYWORDS

Discharge, mass balance, temperature, pollutant, urban river

1 INTRODUCTION

Human activities profoundly modified natural water circulation as well as water quality of rivers, with increased hydrological risks and chemical hazards as consequence. An extreme example of strongly modified river system is the densely populated (1480 inh./km²) river Zenne (Fig.1) crossing the city of Brussels. In and around the city, the river determines a small vertical urbanized area (800 km²), the Brussels Metropolitan Community area, combining extreme land-use landscapes: intensive agricultural activities upstream, a dense cityscape including a forested area in the center, and a strong industrial influence downstream. Part of the upstream base-flow is diverted to feed a navigation canal which is also used as a bypass during flood events, and the river is vaulted over a 7km long stretch in the center of Brussels city. Major human perturbations are intensive agriculture upstream, sewage disposals - treated and untreated via wastewater treatment plants (WWTP) and combined sewer overflows (CSO) in the Brussels conurbation, and industrial effluents downstream (Brion et al, 2015).

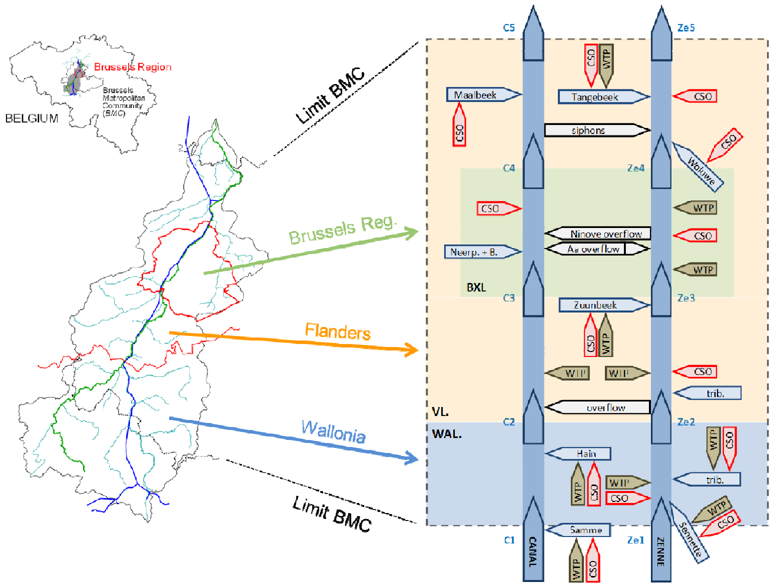

Figure1. Left: Schematic representation of the Zenne River Basin, limits of the Brussels Metropolitan Community (black) dotted lines, and regional limits (red line). Right: Schematic presentation of the various fluxes considered for mass budget calculation in this study with WTP: wastewater treatment plants, CSO: combined sewer overflow.

The objective of our study is to establish a box-model representation of selected polluting chemicals mass budgets (N and P, biological oxygen demand, and a selection of metals, pesticides and PAHs) for variable discharge (Q) (and temperature (T) if relevant) ranges to understand climate effects on the transport/transfer/retention of pollutants within a perturbated river corridor.

2 METHODS

Hydrometric and water quality data were collected for the 2009-2016 period at the boundaries of our studied system and for all most important contributors as presented schematically in Fig.1. Data providers are various regional environmental agencies and wastewater managers. Average daily loads for considered periods were computed as:

$$L = \frac{\sum_k Q_k \cdot \sum_i Q_i C_i}{\sum_i Q_i}$$

with L: load (g/d), Q: daily discharge (m³/d), C: concentration (mg/l), k: days for which Q is available, i: days for which Q and C are available. Comparisons with other methods were performed. When concentration data are scarce (metals in WWTP and CSO or some tributaries) loads were computed by multiplying average Q over the period with average C over the period. For some of the variables (for example Cd or Hg), many reported concentration data are below detection limits (DL) and therefore we choose to work with two datasets. In the first set all concentrations below DL are set to 0, in the second set, all concentrations below DL are set equal to the DL. Average daily loads are then computed for each of the datasets to have a realistic range. Important missing hydrometric data: CSOs in Brussels – only one dataset is validated and there are many others that are important; tributaries upstream Brussels; exchange between Canal and Zenne in Brussels (Zenne to Canal). This is described in detail in the presentation by Carbonnel et al (2018). Chemical mass budgets were computed for various situation: (1) A yearly average situation considering 2009-2016 data, (2) Wet weather conditions considering data when Q at the outlet of the basin is higher than the 75% percentile (P75%) of the 2009-2016 distribution, Dry weather conditions considering data when the discharge Q < 25% percentile (P25%). If relevant, in a later stage we will also consider cold wintry weather and summer warm weather conditions considering T selection criteria. Results are presented as mass balances for the Zenne upstream Brussels, Brussels and downstream Brussels

3 RESULTS AND DISCUSSION

Upstream Brussels, the water mass balance is not closed with still 25 to 30% of the water discharge missing. Hence, WWTP effluents are important contributors for most of the pollutants while industrial effluents are very important for total Cd only (Fig.2a). During dry weather, contributions of external sources increase while during wet weather, all fluxes increase especially for suspended matter (SPM loads multiplied by 30 between dry and wet while by 4 for discharge) and pollutants related to SPM (BOD, total metals, etc…). Inside Brussels, the water mass balance is closed. There is a major contribution of WWTP effluents (representing 50% of the water discharge) for all pollutants (example for BOD, fig.2c) and CSO are also very important for BOD, COD, and total Cu. During wet weather, all fluxes increase and the importance of CSO increase especially for particulate species (example for BOD, fig.2d). Downstream Brussels, the water mass balance is closed. There are no WWTP effluent release in this stretch and tributaries are of minor importance except during wet weather when the canal overflow represents an important N source for the river (Fig.2b).

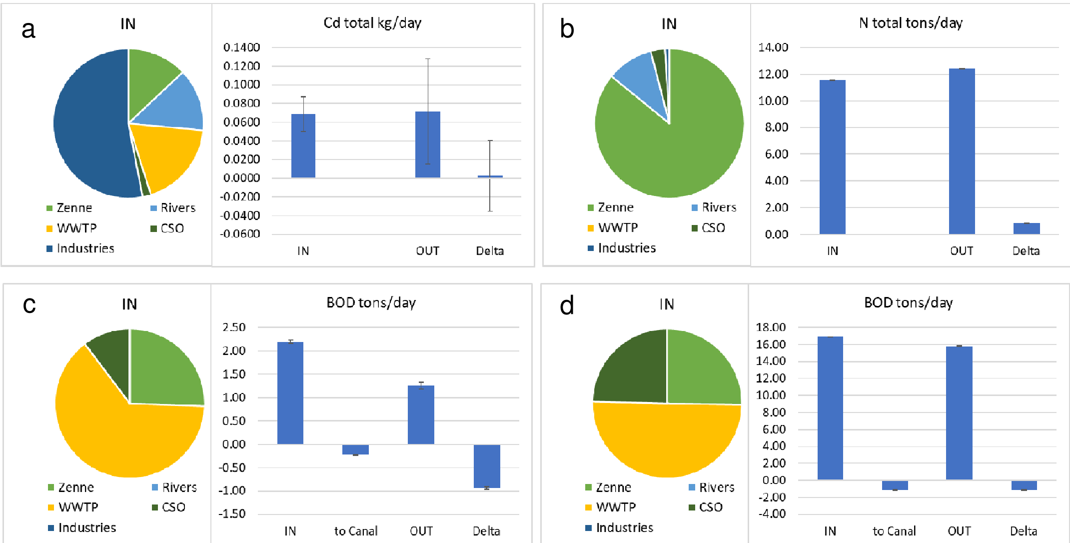

Figure 2. Mass balance in Zenne river stretches for total Cd, N and biological oxygen demand for a. Average situation, upstream Brussels, b. Wet situation, downstream Brussels, c. Dry situation, Brussels and d. Wet situation, Brussels. IN: sum of all inputs; WWTP: wastewater treatment plant; CSO: combined sewer overflow; Rivers: all tributaries including canal overflow to Zenne; to Canal: overflow from Zenne to Canal. Delta: difference between OUT and IN. Error bars: variation between loads obtained when concentrations<LOD are set to 0 and those when they are set to LOD.

4 CONCLUSION

First results allow to conclude that in an urban river receiving important amounts of WWTP effluents: There is a major contribution of WWTP effluents to the loads of most of the pollutants whatever the hydrological situation; There is a major contribution of CSO for wet weather conditions, but also for an average annual situation in Brussels; The loads during wet weather conditions increase much more relative to the water discharge for pollutants linked to particulate material.

LIST OF REFERENCES

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