N4 - Ecosystem metabolism in natural and technical aquatic systems of urban environments

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Background

Urban water bodies are highly modified and stressed ecosystems. They receive large loads of nutrients, organic carbon, suspended solids and a wide variety of macro- and micropollutants, such as heavy metals, pharmaceuticals, or personal care products (Buser et al. 1999, Hatt et al. 2004, Grimm et al. 2005). Furthermore, their morphology has usually been changed (Steele and Heffernan 2013)and habitat heterogeneity has been reduced (Walsh et al. 2005), which limits their ability to support aquatic biodiversity (Ward et al. 2002).The growth of urban areas also brings changes in physical properties of the land surface(Niemczynowicz 1999), such as increased sealing by paved surfaces, which hampers infiltration and accelerates surface runoff with implications for flow regimes of and contaminant delivery to the receiving water bodies. Under all this stressors, urban water interfaces play key roles in the transformation and transport of water, matter, and energy in urban areas (Gessner et al. 2014).

The production of organic matter by photosynthesis and its mineralization by respiration (Odum 1971) are the two constituent processes of ecosystem metabolism (Venkiteswaran et al. 2008). Both are affected by water quality and, in turn, have repercussions for the quality of surface waters. In addition, gas exchange across the water-atmosphere interface couples water bodies with the atmosphere, particularly by CO_2 emissions, which the Intergovernmental Panel on Climate Change (IPCC) has only recently included in its estimates of global carbon fluxes (Ciais et al. 2013). Currently, however, there is a lack of large-scale estimates of ecosystem metabolism and CO_2 fluxes in urban waters. Given the importance and rapid growth of cities worldwide, this is a constraint for accurate estimates of the role of cities in the current and future global carbon cycle.

One important factor to consider when assessing carbon dynamics across the water-atmosphere interface is dissolved organic matter (DOM), which plays multiple roles in aquatic ecosystems, but is particularly important as a substrate fueling heterotrophic activity. The composition of DOM has hence been used as an indicator of past organic matter transformations. In a review focusing on DOM concentrations of surface waters, Stanley et al. 2012 underlined the high spatiotemporal variability in human-influenced waters and concluded that current monitoring and management of DOM is supported neither by a robust mechanistic understanding of DOM dynamics nor by consistent data sets. This situation could potentially be improved by expanding the very limited data base on DOM composition.

Aim of the work

The main objectives of N4 are (Figure 1):

1. Characterize dissolved organic matter (DOM) composition in a variety of urban water bodies, including lakes and ponds as well as running waters, which experience varying degrees of anthropogenic impacts.

2. Estimate carbon dioxide concentrations, their dynamics and resulting fluxes across the water-atmosphere interface for the same water bodies, to identify hotspots expected to occur at the interface of natural and technical aquatic systems, especially where treated wastewater is discharged into receiving waters.
3. Estimate whole-ecosystem metabolism based on diel O_2-dynamics.
4. Identify drivers of metabolism and CO_2 fluxes by exploring the environmental variation across the investigated sites in Berlin (Figure 1).

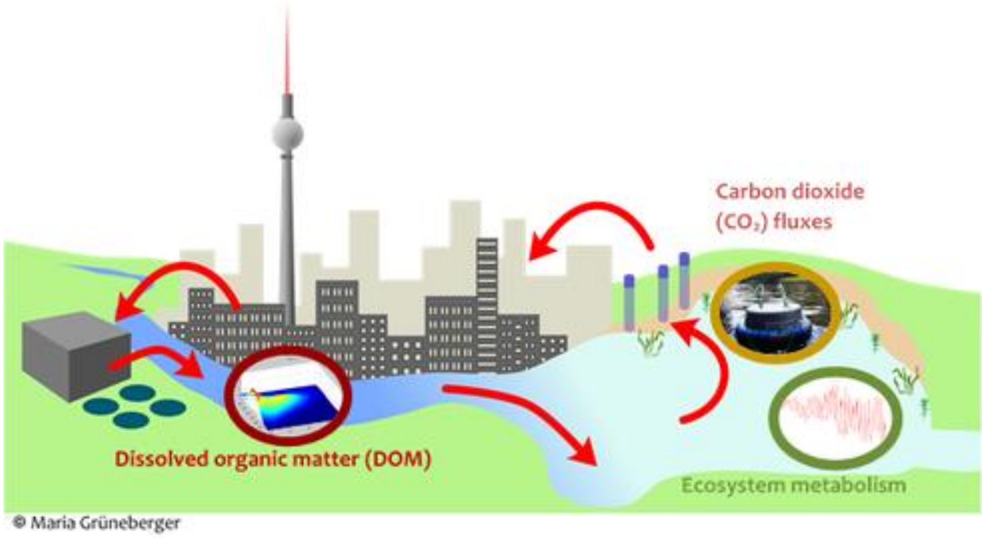

Figure 1: Graphical representation of the main aims of N4: characterize dissolved organic matter, estimate carbon dioxide fluxes across the water-atmosphere interface and calculate whole-ecosystem metabolism of urban water bodies.

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Methods

A total of 32 sites have been selected within the city limits of Berlin following a stratified random sampling design. The selected sites include lakes, ponds, streams and rivers. These water bodies were sampled during four periods over one year: in spring (April-May 2016), summer (July-August 2016), autumn (September-October 2016) and winter (February-March 2017).

DOM concentration and composition was investigated at each site by using a range of techniques, including absorbance and fluorescence spectroscopy, size exclusion chromatography and ultra-high resolution mass spectrometry. In addition, water chemistry including various pollutants and nutrient species was extensively characterized at each sampling occasion.

To estimate CO_2 fluxes the dynamics of CO_2 concentration were measured in the headspace of floating chambers using an Ultraportable Greenhouse Gas Analyzer (figure 2, UGGA, Los Gatos Research, Inc., USA) water pCO_2 and atmospheric concentrations were also measured.

Figure 2: Using a Los Gatos Ultraportable Greenhouse Gas Analyzer to determine CO2 fluxes across the water-atmosphere interface in the River Spree (Berlin) in February 2017.

Oxygen probes (miniDOT DO optodes, PME, Vista, CA, USA) were also deployed at all sites during one week in each season. To determine whole-ecosystem metabolism, a differential equation model (Van de Bogert et al. 2007, Urai et al. 2014, Song et al. 2016) will be fit to the diel changes in dissolved oxygen concentrations measured at a single station at each site (Odum 1956). The model will simulate diel changes in dissolved oxygen concentration as a result of parameterized gross primary production (GPP), ecosystem respiration (ER) and reaeration (Fuß et al. 2016).

Preliminary results

First results indicate significant variation in the DOM composition at the 32 investigated urban water bodies. Furthermore, we found that in all seasons CO_2 fluxes from all sites were generally positive (CO_2 emissions) and higher than measured in natural waters. However, both temporal and spatial variability of CO_2 fluxes and DOM composition were high. Strong relationships with individual environmental variables, including concentrations of dissolved nutrients and a range of micropollutants, were not detected.

Collaborations

- N3 (Sonia Herrero) and T5 (Geert Aschermann).
- Common topics: Biogeochemical processes, Modelling, Micropollutants and Interfaces in urban surface waters.

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