The Footprint of Urbanization: Diurnal pattern of physico-chemical parameters in an urban stream

L'empreinte de l'urbanisation : schéma diurne des paramètres physico-chimiques dans un cours d'eau urbain

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RÉSUMÉ

Les capteurs installés sur les cours d'eau enregistrent non seulement les concentrations d'une substance, mais aussi, indirectement, les effets des processus moteurs et des conditions limites dans le milieu aquatique sur l'analyte. Dans ce résumé, nous voulons montrer comment les profils journaliers de l'O2, du pH, de la température et du CO2 varient dans un sous-bassin versant urbanisé d'un cours d'eau. Pour cela, nous comparons les enregistrements des capteurs de deux stations de surveillance, l'une située dans la ville de Dresde et l'autre avant que le cours d'eau n'atteigne la ville. Nous relions ces résultats aux différences d'aspect du cours d'eau, aux modifications de sa section transversale et de ses berges, ainsi qu'à la disponibilité des nutriments. Tous les schémas diurnes enregistrés dans la ville montrent une augmentation de l'amplitude quotidienne, les maxima et minima quotidiens atteignant des niveaux plus élevés et plus bas que dans le sous-bassin rural, tandis que les valeurs moyennes ne diffèrent pas beaucoup. À l'aide de la transformation de Fourier et de l'analyse de régression, nous avons créé un sous-ensemble de données pour les jours qui n'ont été exposés qu'à des conditions météorologiques claires. Ces jours ont été analysés afin d'étudier les changements saisonniers, le moment d'apparition des valeurs maximales quotidiennes et les différences entre ces moments d'un paramètre à l'autre. Nous avons observé que les distances entre les maxima des paramètres étaient plus longues en hiver, tandis qu'elles diminuaient en été. Les différences entre les deux stations sont également évidentes, avec des décalages nettement plus courts sur le site de surveillance urbain pour tous les paramètres. Nous supposons que des activités métaboliques plus élevées (exprimées par les profils d'O2 et de CO2) ont des effets importants sur l'équilibre du carbonate de calcium et donc sur la valeur du pH. Nous envisageons que ces relations puissent être utilisées pour détecter les effets de la disponibilité croissante des nutriments ainsi que pour évaluer les efforts de renaturation dans les cours d'eau urbains

ABSTRACT

Sensors mounted streams do not only record concentrations of a substance but also indirectly the impacts of driving processes and boundary conditions in the waterbody on the analyte. In this abstract we want to show how diurnal patterns of dissolved oxygen (DO), pH, Temp and CO_2 change within an urbanized subcatchment of a stream. Therefore, we compare sensor recordings from two monitoring stations, one in the city of Dresden and another one before the streams reaches the city. We link these findings to differences in the appearance of the stream, alterations in the cross-sections and riverbanks as well as the availability of nutrients. All recorded diurnal patterns in the city show an increase in daily amplitude, the daily maxima and minima reach higher and lower levels than in the rural sub catchment while mean values do not differ much. Using Fourier transformation and regression analysis we created a subset of data for days that were only exposed to clear weather conditions. These days were analysed for changes in seasonality, the occurrence time of daily maximum values and how these times differ from parameter to parameter. We observed that distances between maxima of parameters were longer in the winter season while in summer they decreased. Differences between the two stations are obvious as well with significantly shorter lag times at the urban monitoring site for all parameters. We assume that higher metabolic activities (expressed by O_2 and CO_2 patterns) have strong effects on the calcium carbonate equilibrium and thereby on the pH value. We envisage that these relations can be used to detect effects of increasing availability of nutrients as well as for the assessment of renaturation efforts in urban streams.

KEYWORDS

Diurnal patterns, online monitoring, urban stream syndrom, urbanization, water quality

1 INTRODUCTION

The advantages of online water quality motoring over grab sampling for constant surveillance and assessment of event dynamics are indisputable (Skeffington et al., 2015). However, there is only a limited number of parameters that can be monitored in a high temporal frequency and often the effort to maintain these sensors can be high. In order to optimize the information that can be gathered from high resolution physico-chemical monitoring we want to demonstrate the possibilities of using additional temporal information in a soft sensors concept with water quality parameters. We focus on well-established physico-chemical sensor like temperature, pH, dissolved Oxygen and dissolved CO_2. Those four parameters have a distinguished diurnal pattern, mainly influenced by the ambient weather conditions and solar radiation (Rocher-Ros et al., 2025). While dissolved oxygen, temperature and pH have reach a peak during daytime, dissolved CO_2 shows an inverted behaviour. We extracted explanatory information from these diurnal patterns and want to evaluate if these signals can be used to detect effects of the urban stream syndrome within our monitoring network (Walsh et al., 2005). An important factor is the increase in water temperatures often found in urban areas, which is expected to lead to higher rates of ecosystem processes like biological productivity and stream metabolism (Kaushal et al., 2010)

2 MATERIAL AND METHODS

2.1 Catchment

Measurements are taken at Lockwitzbach, a small stream, with a length of 24 km. Its catchment area is about 84 km². The stream shows different characteristics along its course. Upstream of the city of Dresden, the appearance is rural, while in the municipality these characteristics changes significantly. The rural part has a low population density and only 3,8% impervious surface. In the municipality the streambed becomes straightened and the imperviousness increases to 41% (see Figure 1). The Urban Hydrology Research Group of TU Dresden operates two modular online monitoring at the stream (MS6 & 4). The upper monitoring station is located at the border between the rural and urban sub catchment and the second one after a flow distance of ca. six kilometers, shortly before the confluence with the river Elbe.

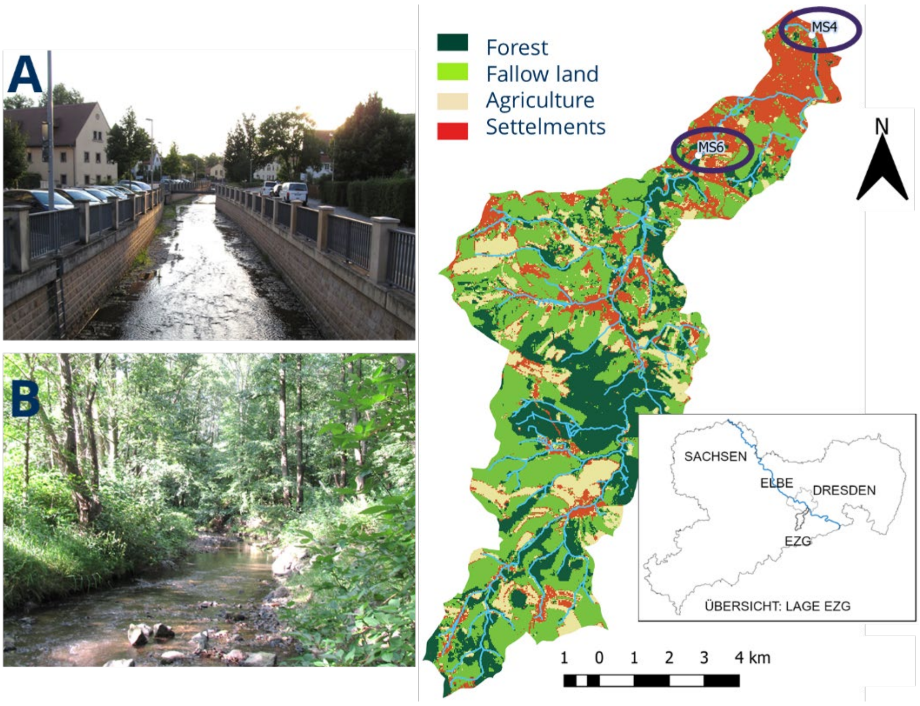

Figure 1: Catchment and landuse of Lockwitzbach, monitoring stations are marked with circles ; picture A: Urban sub-catchment, picture B : rural sub-catchment

2.2 Sensors

The sensors used in this study are listed in Table 1. The CO_2 sensors are installed since April 2025 at the two monitoring stations, dissolved oxygen, pH and water temperature are in operation since nine years.

Table 1: Sensors used at both monitoring stations

Sensor		Parameter
LDO sc	(HACH, USA)	diss. O_2, Temp.
1200-S sc	(HACH, USA)	pH, Temp.
CO_2 Sensor	(AMT, Germany)	diss. CO_2

2.3 Data Selection

A pre-selection of data was necessary to find diurnal pattern that are not affected by changes in climatic conditions like rain events or clouded sky. Therefore, we split the data into single days and fit a two order Fourier series. Assuming that more complex patterns than simple diurnal patterns (e.g in Figure 2) yield a higher relative root mean square error, we used this method as a filtering criteria. Furthermore, we split the data into summer (May-September) and winter (October-April).

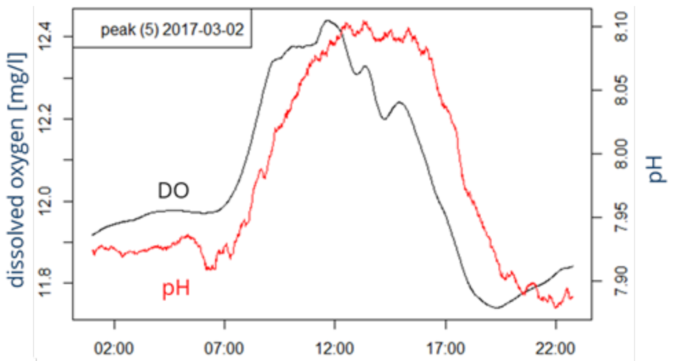

Figure 2 : Complex diurnal pattern of dissolved oxygen and pH at MS4

3 RESULTS AND DISCUSSION

There were 203 days at MS4 and 231 days at MS6 available for analysis in the investigation period from 2023 till 2025 after the data selection process. During winter season we found mean amplitudes of 4.2 ± 2.8 mg/l DO, 0.8 ± 0.4 pH and 6 ± 1.8 °C at the urban and 1.5 ± 0.7 mg/l DO, 0.2 ± 0.2 pH and 3.2 ± 1.6 °C at the rural monitoring station. Amplitudes during summer are considerably bigger at MS4 (6 ± 2.3 mg/l DO, 1 ± 0.3 pH and 3.6 ± 1.9 °C) compared to MS6 (1.1 ± 0.3 mg/l DO, 0.2 ± 0.1 pH and 3.4 ± 1 °C).

The pH peaks always after the DO (e.g. Figure 3). During summer we find a higher gap time between maxima of pH and DO for MS6 (4.7 ± 3 hours) than at MS4 (3.4 ± 3.4 hours). With shorter lag times this is trend appears in winter as well (MS6: 3.6 ± 2.2 hours and MS4: 2.7 ± 1.8 hours). Looking at the time lag between the maximum of DO and water temperature we did not found a seasonal change but a significant difference between the monitoring stations (MS4: Summer: 3.2 ± 1.7 hours / Winter: 3.3 ± 2.2 hours, MS6: Summer: 7.7 ± 2.9 hours / Winter: 7.4 ± 4.1 hours). Similar to DO & pH the maximum dissolved oxygen concentration is reached before the maximum temperature. The relation between the daily maximum of pH and water temperature does not show this consistent trend. There is an indication for a seasonal difference at MS6 (Summer: 3 ± 4 hours / Winter: 4.3 ± 4.6 hours), however the pH maximum occurs in almost all cases before the water temperature reaches the highest daily value. At MS4 this condition does not appear that obvious, the water temperature maxima during winters are a bit later than the pH maxima. During summer they appear rather close to each other (Summer: 0.3 ± 2.1 hours / Winter: 0.7 ± 2.3 hours).

Since the sensor for CO2 is only available since April 2025 on both stations we excluded it from a seasonal analysis in this abstract. Seasonal data for this parameter is going to be shown at the conference, when the time series is going to be longer than one year.

We assume that little shading as well as a surplus of nutrient supply significantly enhanced stream metabolism is in the urbanized section of the stream. This can be obviously seen by heavy increases in amplitudes during summer at MS4 for all parameters or the time lag between DO and water temperature maxima. Due to increased photosynthetic performance CO_2 is consumed, resulting in a shift in the calcium-carbonate equilibrium and an increase in pH. The time-lag between the DO and pH peak could be depending on the buffer capacity of the stream water, which would explain the differences between the summer and winter time-lags.

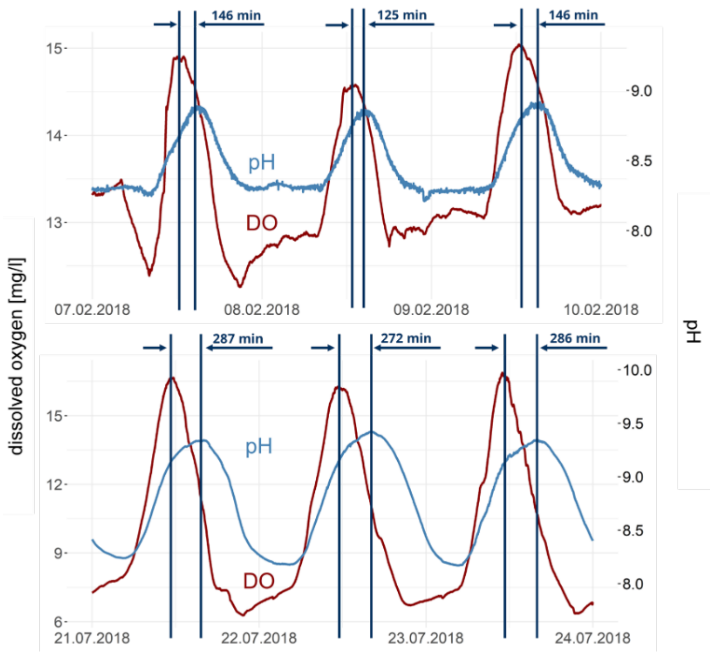

Figure 3 : Upper graph : Diurnal patterns of pH and dissolved oxygen at MS4 during winter (Feburary), Lower graph : Diurnal patterns of pH and dissolved oxygen at MS4 during summer (July)

How the time lag between water temperature and pH could be explained is still unclear for us, we are going to evaluate this further until the conference. We did not consider a similar comparison with daily minima instead of maxima to prove whether similar patterns occur there as well. These relations can be used to detect effects of increasing availability of nutrients as well as for the assessment of renaturation efforts in urban streams.

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