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Viscosity changes of riparian water controls diurnal fluctuations of stream-flow and DOC concentration

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Diurnal fluctuations in stream-flow are commonly explained as being triggered by the daily evapotranspiration cycle in the riparian zone, leading to stream flow minima in the afternoon. While this trigger effect must necessarily be constrained by the extent of the growing season of vegetation, we here show evidence of daily stream flow maxima in the afternoon in a small headwater stream during the dormant season. We hypothesize that the afternoon maxima in stream flow are induced by viscosity changes of riparian water that is caused by diurnal temperature variations of the near surface groundwater in the riparian zone.

The patterns were observed in the Weierbach headwater catchment in Luxembourg. The catchment is covering an area of 0.45 km^2, is entirely covered by forest and is dominated by a schistous substratum. DOC concentration at the outlet of the catchment was measured with the field deployable UV-Vis spectrometer spectro::lyser (scan Messtechnik GmbH) with a high frequency of 15 minutes over several months. Discharge was measured with an ISCO 4120 Flow Logger. During the growing season, stream flow shows a frequently observed diurnal pattern with discharge minima in the afternoon. During the dormant season, a long dry period with daily air temperature amplitudes of around 10 $^{\circ}$C occurred in March and April 2014, with discharge maxima in the afternoon. The daily air temperature amplitude led to diurnal variations in the water temperature of the upper 10 cm of the riparian zone. Higher riparian water temperatures cause a decrease in water viscosity and according to the Hagen-Poiseuille equation, the volumetric flow rate is inversely proportional to viscosity. Based on the Hagen-Poiseuille equation and the viscosity changes of water, we calculated higher flow rates of near surface groundwater through the riparian zone into the stream in the afternoon which explains the stream flow maxima in the afternoon. With the start of the growing season, the viscosity induced diurnal effect is overlain by the stronger influence of evapotranspiration.

Diurnal DOC fluctuations show daily maxima in the afternoon. While daily variations in DOC concentrations are often explained by faster in-stream biogeochemical processes during daylight, we here propose that the viscosity effect in the riparian zone could explain the afternoon peaks in DOC concentrations. Our records show that daily water temperature variations and therefore viscosity changes only occur in the near surface parts of the riparian zone, where the DOC concentrations are higher than in deeper parts of the riparian zone. We calculated, that the viscosity induced higher flow rates from the near surface parts of the riparian zone can explain the DOC concentration maxima in the afternoon. As the viscosity effect does not disappear during the growing season but is just smaller than the evapotranspiration effect, the DOC concentration pattern is not changing between the dormant and growing seasons. The different controls of diurnal fluctuations of stream-flow and water quality concentrations need to be carefully considered in order to better understand the different patterns in catchment hydrology.