A New Optical Oxygen Sensor Reveals Spatial and Temporal Variations of Dissolved Oxygen at Ecohydrological Interfaces

Tanja Brandt[1*], Michael Vieweg[1], Astrid Harjung[2], Jan H. Fleckenstein[1], and Christian Schmidt[1]

* contact: tanja.brandt@ufz.de

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

We explored:

Spatio-temporal dynamics of Dissolved Oxygen (DO) at a highly reactive interface, the **Hyporheic Zone**

We developed:

miniDOS – a **m**iniaturized **D**istributed **O**xygen **S**ensor for semi-automated, spatially continuous DO profiling

We found:

Sharp, persistent DO transition zone in the streambed, likely controlled by changing hydrological conditions

Background

The hyporheic zone is the site of intensive biogeochemical cycling in streams, however, the controls on spatio-temporal variability in hyporheic processing are largely unknown. Here, the distribution of dissolved oxygen (DO) is of particular interest since it serves as primary indicator of redox and interlinked biogeochemical zonation.

Continuous measurements of DO over time and depths is challenging due to the dynamic and potentially heterogenic nature of the HZ, especially with regard to potential hotspots and hot moments. Our new oxygen sensing technology allows precise and high-resolution monitoring of spatio-temporal oxygen distributions in these highly dynamic environments.

Field site

Fuirosos stream, Spain

- Seasonally *intermittent* → flow cessation in Summer
- Repeated DO measurements in the HZ during cessation of surface flow (June - July 2015)
- 2 locations within 80 m reach:
  - (a) up- and (b) downstream of pool-cascade sequence

Fig. 1: Locations of repeated DO measurements in the HZ of the Fuirosos stream: (a) upstream and (b) downstream of pool-cascade sequence with (c) tubular oxygen probe installed in the streambed

Technology

- **m**iniature **D**istributed **O**xygen **S**ensor (**miniDOS**)
- Method further developed from Vieweg et. al (2013)
- Based on optical sensing, i.e. luminescence quenching of an oxygen-sensitive dye

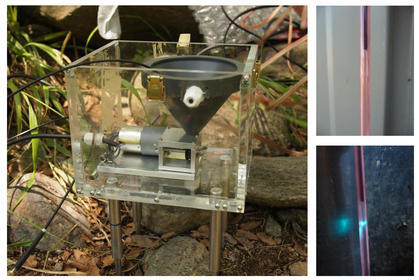

Fig. 2: Prototype of the miniDOS prior to installation *in situ*. Left panel: control unit (not shown here: battery, fiber optic oxygen transmitter, battery). Right panels: side-firing POF in tubular oxygen probe.

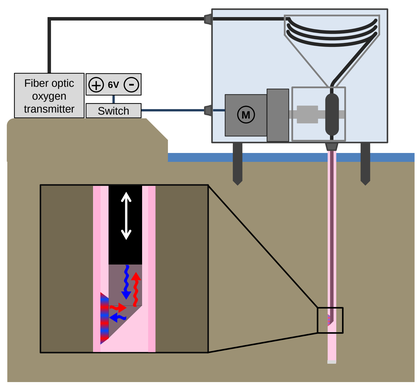

Fig. 3: Conceptual design of the miniDOS with tubular oxygen probe and control unit (not to scale).

Key features

+ Continuous vertical oxygen profiles with mm resolution
+ Fast, reliable measurements
+ Minimally invasive
+ No oxygen consumption
+ Minimal flow disturbance
+ Robust, waterproof design
+ Suitable for long term installation *in situ*

Control unit

- Motorized side-firing Polymer Optical Fiber (POF), ø 2 mm

Tubular oxygen probe

- Clear acrylic tube dipcoated with oxygen sensitive dye (PtTFPP-polystyrene matrix)
- Outer/Inner diameter: 5/3 mm

Initial results

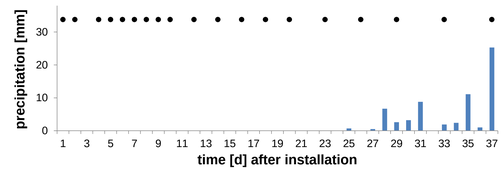

Fig. 4: Schedule of repeated DO measurements (black circles) at both locations and precipitation on location (La Battloria, Spain)

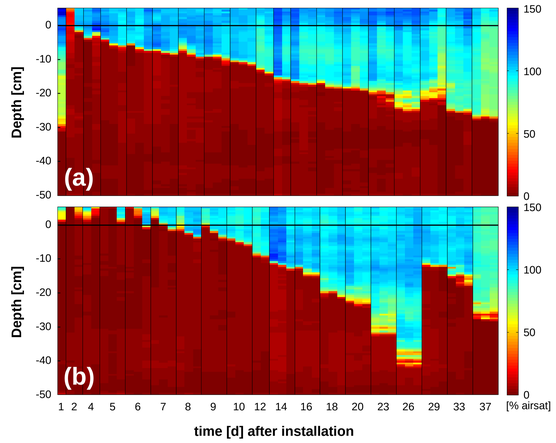

Fig. 5: Vertical oxygen distribution during cessation of surface flow (transition from saturated to unsaturated conditions) in the Hyporheic Zone of the Fuirosos stream (a) up- and (b) downstream of a pool-cascade sequence.

Outlook

- Optimize technology towards a full automated, remote-controlled stand-alone system
- Identify primary controls of oxygen dynamics and interlinked biogeochemical cycling at different ecohydrological interfaces

Affiliations:

1) Helmholtz Center for Environmental Research - UFZ, Leipzig, Germany
2) University of Barcelona, Spain

Reference:

Vieweg, M., Trauth, N., Fleckenstein, J. H., Schmidt, C. (2013): Robust Optode-Based Method for Measuring in Situ Oxygen Profiles in Gravelly Streambeds. Environmental Science & Technology. doi:10.1021/es401040w

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interfaces