Flow dynamics and resulting reactivity in the transition zone between streams and riparian aquifers

Poster · April 2019

DOI: 10.13140/RG.2.2.19515.26403

4 authors:

Guilherme Emídio Horta Nogueira
IHE Delft Institute for Water Education

Christian Schmidt
Helmholtz-Zentrum für Umweltforschung

Nico Trauth
Björnsen Consulting Engineers

Jan Fleckenstein
Helmholtz-Zentrum für Umweltforschung

Flow Dynamics and Resulting Reactivity in the Transition Zone between Streams and Riparian Aquifers

Guilherme Nogueira[1], Christian Schmidt[1], Nico Trauth[2] and Jan H. Fleckenstein[1]

1- Helmholtz Centre for Environmental Research - UFZ, Department of Hydrogeology, Leipzig, Germany
2- Björnsen Consulting Engineers, Leipzig, Germany

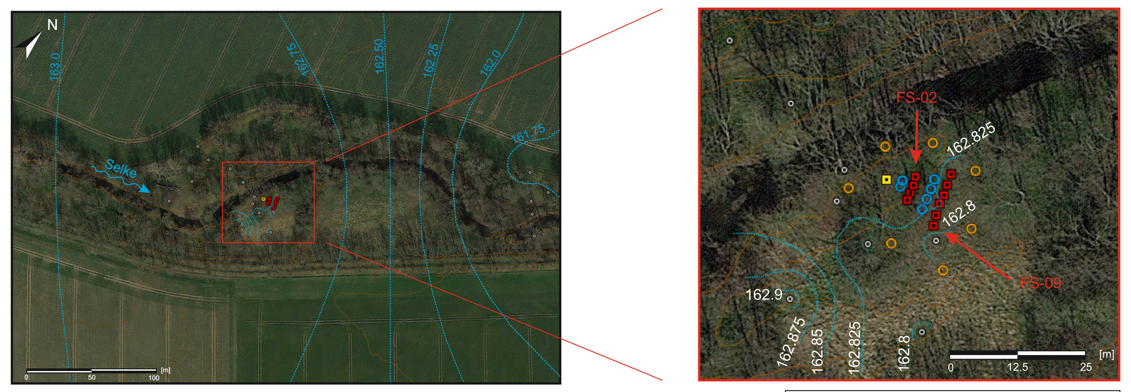
HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

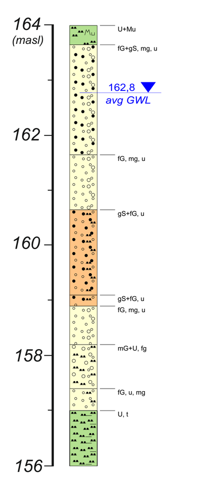
1 Introduction

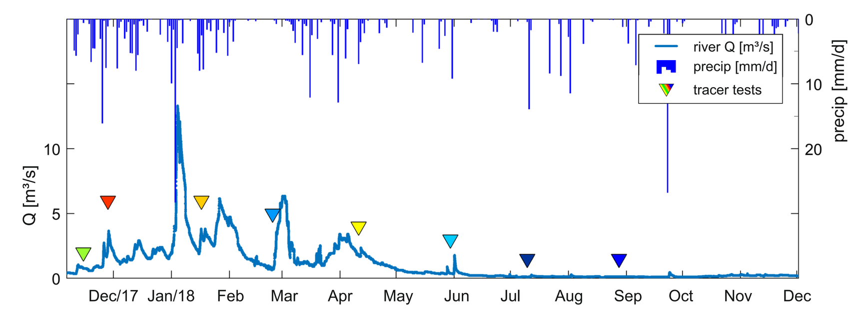
Stream-groundwater mixing zones are well known for their role in facilitating ecosystem metabolism which also results in enhanced water quality (e.g. by denitrification). However, due to their highly dynamic biogeophysical characteristics (i.e. temperature, flow directions, residence times), a simple and general quantification of the reactivity potential is not readily possible.

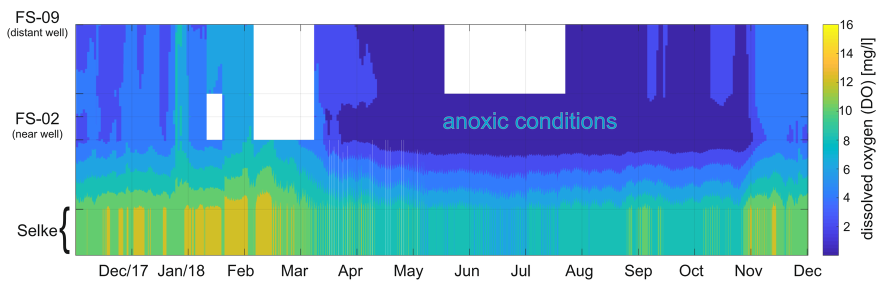
Here, we combined conservative and reactive tracer-tests with high frequency measurements of electrical conductivity (EC) and dissolved oxygen (DO) to enhance the understanding of the hydraulic variations on aquifer's reactivity potential. We analysed the reactivity in terms of Damköhler numbers (DA) and assess its patterns over time and space, while comparing its dependency on *short* and *long* term temperature and river discharge fluctuations.

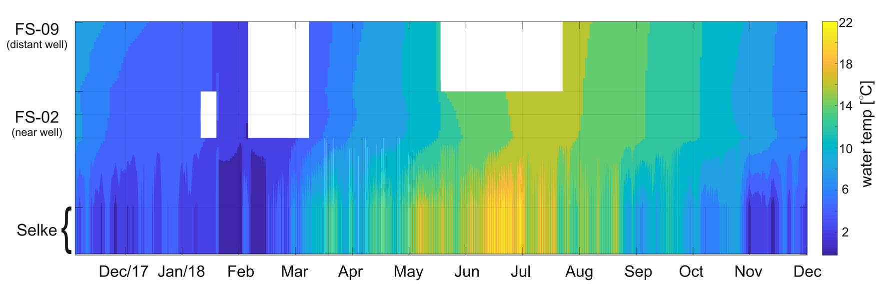
2 Field site and measurements







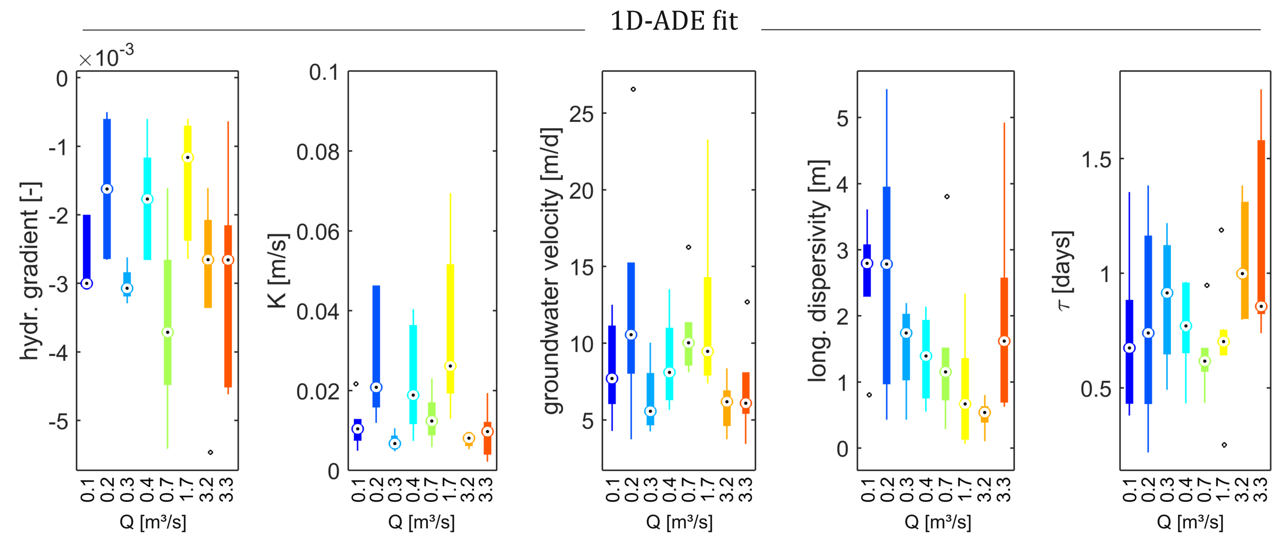




Selke River - tracer tests were conducted in the riparian aquifer under different ambient conditions by using salt added to river water.

LTC and DO loggers placed in different wells and depths to capture tracer breakthrough curves with high horizontal and vertical resolutions.

3 Results



Spearman's rank correlation for tracer test parameters

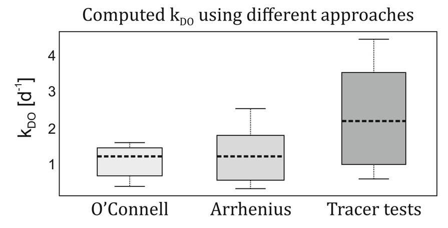
	Q [m³/s]	Δ temp	GW temp
k_DO	- 0.71	0.66	0.79
travel times (τ)	0.24	- 0.08	- 0.06
GW temp	- 0.72	0.58	1

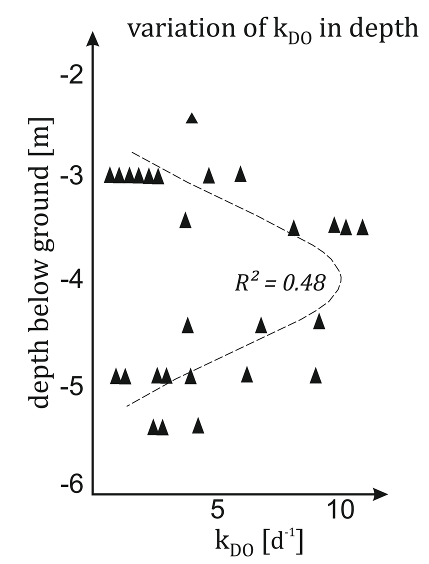
Derived travel times [*days*] from different methods

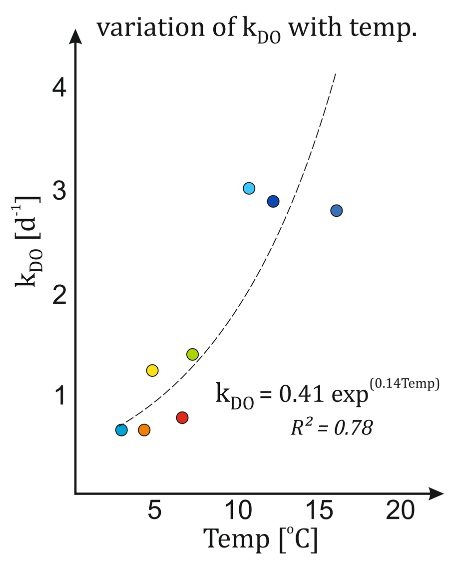
	τ. tracer test	τ. deconv	τ. cross correl
FS-02	0.3 - 1.05	1.20	0.1 - 1.7
FS-09	0.7 - 1.6	1.58	0.2 - 1.8

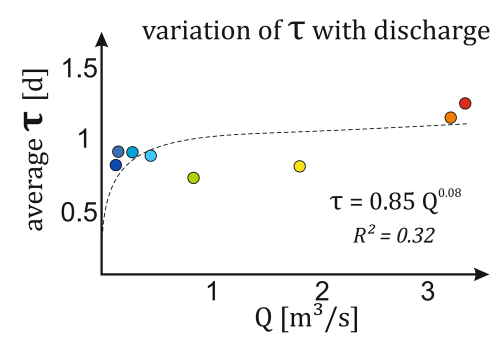
100 realizations were made for τ deconvolution; for cross correlation anaylses, a fixed window size was chosen.

Computed k_{DO} using different approaches

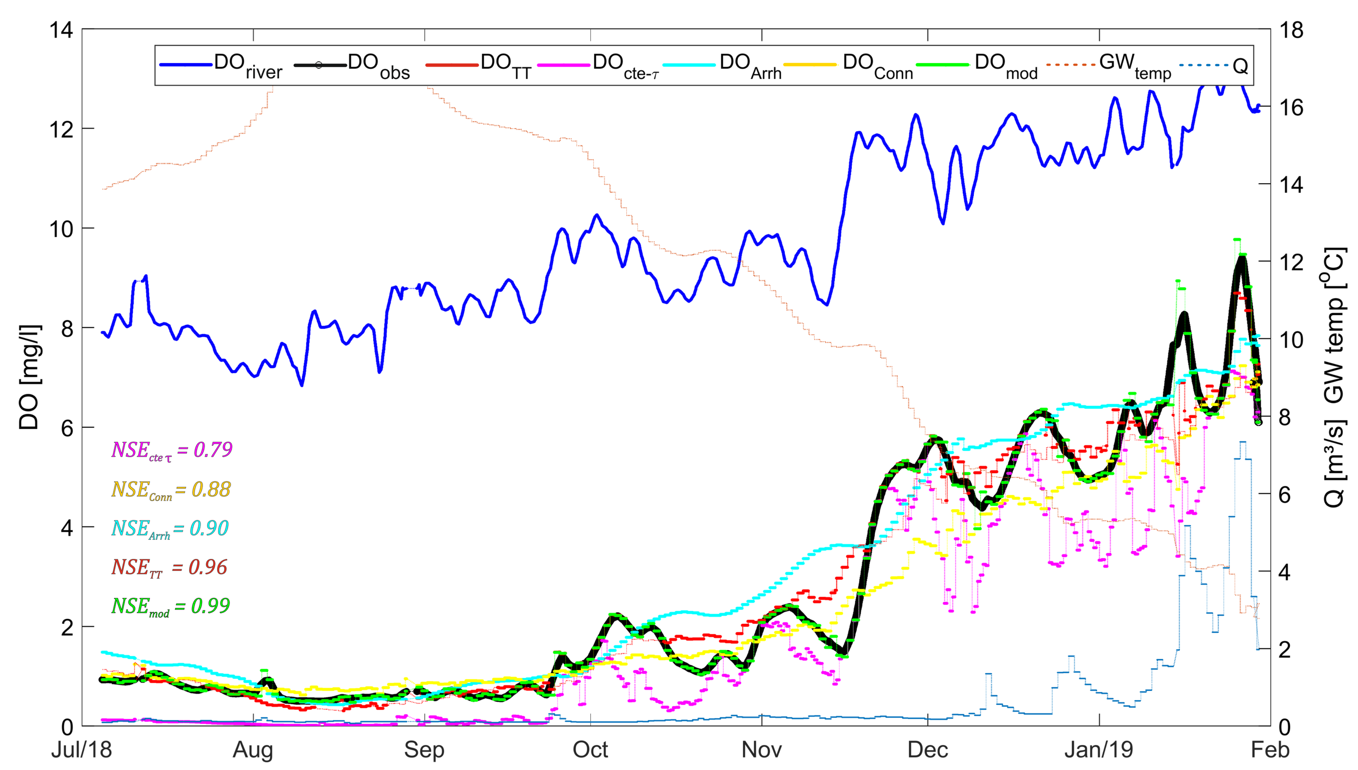








Travel times were derived as a power law from river discharge; respiration rates exponentially related to water temperature.

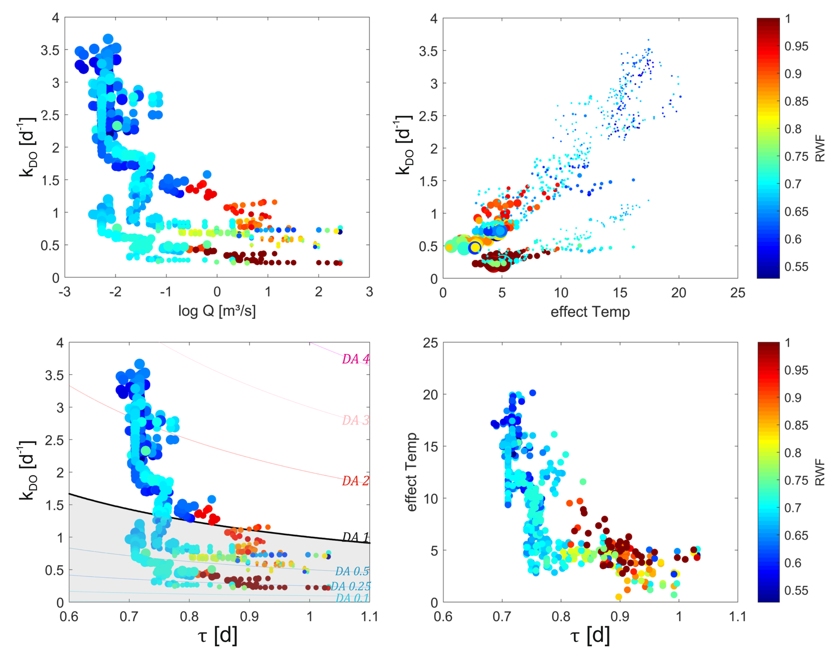


Parameters used in the models

Model	τ [d]	k_{DO} [d^{-1}]
DO_{TT}	tracer tests	tracer tests (*effect temp*)
$DO_{cte\tau}$	constant, deconv.	tracer tests (*effect temp*)
DO_{Arrh}	tracer tests	Arrhenius equation
DO_{Conn}	tracer tests	O'Connell equation
DO_{mod}	tracer tests	Arrhenius (*effect temp*)

Model's performances increase when an effective temperature (between groundwater and river water) is fitted.

4 Conclusions



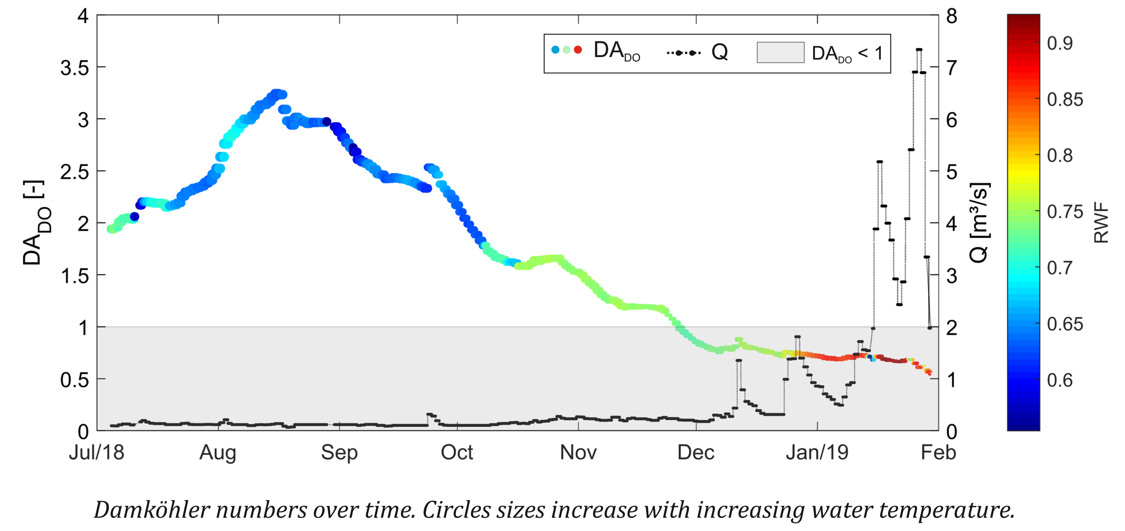
Temperature variations have the greatest effect on respiration rates (85% of k_{DO} variance, data not shown);

Respiration rates (between 0.5 and 4 [d^{-1}]) are negatively correlated (-0.52) with travel times (τ);

Higher river water fraction (RWF) in the aquifer does not necessarily leads to greater DO consumption rates.

System changes from transport limited (DA>>1) to reaction limited (DA<<1) with increasing *Q* (lowering of temperatures;

Balanced conditions (DA~1) when RWF is between 70% and 90%, and temperatures are moderate.



Damköhler numbers over time. Circles sizes increase with increasing water temperature.

5 Synthesis and Outlook

- Travel times and k_{DO} derived from tracer tests and different methods are within the same order of magnitude, and well represent the system dynamics;
- Warm periods, resulting in high *DA* numbers, may lead to extremely anoxic conditions and higher denitrification potential.
- Extend the analyses to longer periods and different climatic context;
- Calibration of transient numerical model to assess impacts of reactivity variations on redox sensitive species turnover.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement Nº 722028 (ENIGMA ITN)

Contact: Guilherme Nogueira
Helmholtz Centre for Environmental Research - UFZ,
Permoserstraße 15, 04318 Leipzig, Germany,
guilherme.nogueira@ufz.de

References: Diem, S., Cirpka, O.A., Schirmer, M., *2013a*. Modeling the dynamics of oxygen consumption upon riverbank filtration by a stochastic-convective approach. J. Hydrol. 505, 352–363. https://doi.org/10.1016/j.jhydrol.2013.10.015

Trauth, N., Musolff, A., Knöller, K., Kaden, U.S., Keller, T., Werban, U., Fleckenstein, J.H., *2017b*. River water infiltration enhances denitrification efficiency in riparian groundwater. Water Res. 130, 185–199. https://doi.org/10.1016/j.watres.2017.11.058

Vieweg, M., Kurz, M.J., Trauth, N., Fleckenstein, J.H., Musolff, A., Schmidt, C., *2016*. Estimatingtime-variable aerobic respiration in the streambed by combining electrical conductivity and dissolved oxygen time series. J. Geophys. Res. Biogeosciences 121, 2199–2215. https://doi.org/10.1002/2016JG003345

MARIE CURIE ACTIONS

ITN Enigma

Photography encouraged