Intrinsic potential and activity of nitrate turnover examined for different hydrogeological aquifer settings

John Lester Pide[1], Johann Holdt[2,4], Vitor Patricio Cantarella[3], Adrian Mellage[3], Olaf A. Cirpka[4], Carsten Leven-Pfister[4], Jan-Peter Duda[2], Daniel Buchner[2], Christian Griebler[1]

[1]Department of Functional and Evolutionary Ecology, University of Vienna, [2]Department of Geobiology, University of Göttingen, [3]Institute for Water, Waste, Environment, University of Kassel, [4]Department of Geosciences, University of Tübingen

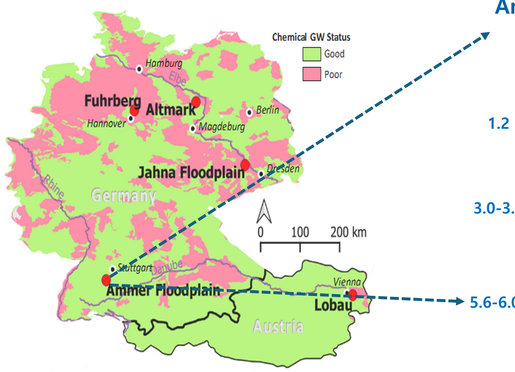
EGU24-18568

INTRODUCTION

- **Nitrate (NO_3^-) is one of the most serious contaminants in groundwater**, frequently deteriorating water quality and its use as drinking water.
- However, NO_3^- can, at specific environmental conditions, be removed within the subsurface environment via natural biogeochemical processes, such as **denitrification and dissimilatory nitrate reduction to ammonium (DNRA)**.
- NO_3^- reduction mostly depends on two key factors, i.e. **the prevalence of hypoxic or anoxic conditions and the availability of a suitable electron donor**, be it organic or inorganic.
- For a long time, research concentrated mainly on the **NO_3^-** attenuation potential and activity in groundwater, **ignoring the aquifers' sediment matrix.**
  - We hypothesize that the **sedimentary deposits host the major potential for NO_3^- reduction**, carrying the majority of microorganisms as well as different sources of electron donors.
- Our goal is to **understand the overall potential and in situ activity of NO_3^- removal in different shallow aquifers** related to their **NO_3^- load, redox conditions, hydrogeology, and microbial community characteristics.**

METHODS

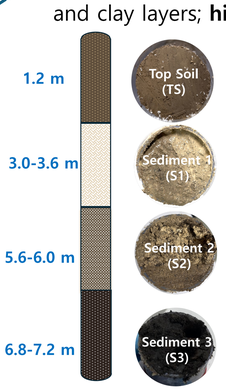
Collection of sediment cores and groundwater



Green versus pink zones delineate areas of "good" versus "poor" groundwater quality with respect to NO_3^- concentration, as categorized according to the European Water Framework Directive.

Ammer Floodplain

Holocene sediments with calcareous sands (tufa) interbedded with peat and clay layers; **highly reduced condition; ↑ sulfide**



Intact sediment cores were collected using a Geoprobe® Model 6610DT direct push device.

Experimental Design

1. Without NO_3
2. With NO_3 (**50 mg/L**)

X

a. Groundwater (**GW**) only
b. GW + **S1** (Tufa)
c. GW + **S2** (Tufa and some mixed peat)
d. GW + **S3** (Peat)
e. Tap water + 1 ml GW + **TS** (Clay)

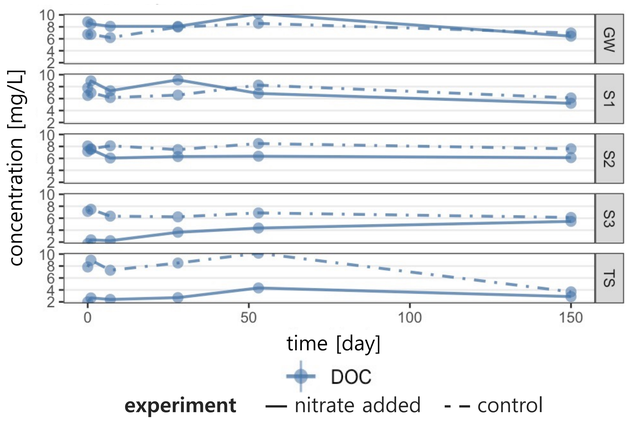
Batch Experiment

Groundwater Chemistry

Analyses	Concentration(mg/L)
TN	12.5
$N\text{-}NO_3^-$	Not detected
$N\text{-}NO_2^-$	0.0007
$N\text{-}NH_4^+$	21.0
$S\text{-}HS^-$	355.0
$S\text{-}SO_4^{2-}$	30.0
DOC	7.3

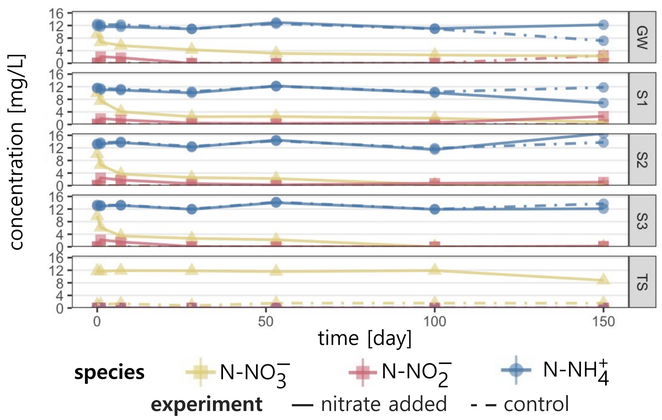
FIRST FINDINGS

Dissolved Organic Carbon (DOC)



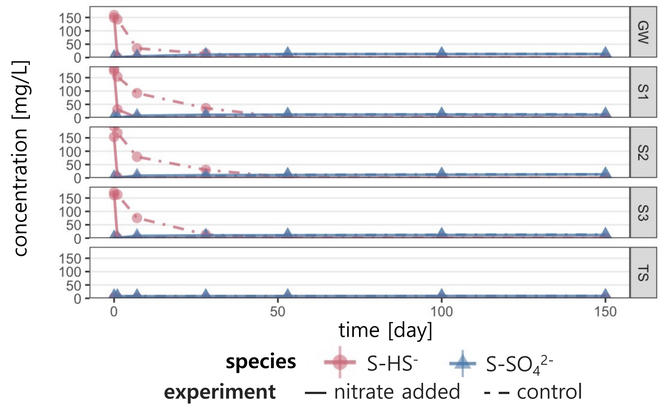
- Highlighting some of the preliminary data of the Ammertal aquifer samples.
- Among samples, there has been a **slow decrease in DOC concentration since day 01 until day 150** indicating that in the **early phase heterotrophic denitrification is not a predominant process.**

Nitrogen species



- The highly reducing capacity of the Ammertal floodplain **led us to anticipate a reduction in NO_3^- levels within the samples**, which was reflective throughout the observation period from Day 1 to Day 150.
- **Consistent decline in N-NO_3^- concentration among samples** were observed.
- **No observable change in $N\text{-}NO_2^-$ concentration.**
- Addition of 50 mg/L NO_3^- after 100 days of incubation, the **$N\text{-}NH_4^+$ concentration remained relatively stable**, ranging from 12 to 14 mg/L, **in contrast to the changes observed in N-NO_3^- levels.**
- This lack of quantitative conversion of NO_3^- into NH_4^+ suggests that **DNRA is not the dominant process occurring in this context.**

Sulfur species



- In both groundwater and sediment samples, there is a **gradual decrease in $S\text{-}HS^-$ concentration**.
- **When treated with 50 mg/L NO_3^-, the decrease is notably faster**, becoming undetectable after Day 7 compared to the control and untreated samples, which suggests a **strong indication that N-NO_3^- reduction is coupled to $S\text{-}HS^-$ oxidation, indicative of autotrophic denitrification activity at play**.
- However, since **only low concentrations of $S\text{-}SO_4^{2-}$ were observed**, **$S\text{-}HS^-$ oxidation likely stops at intermediate S species.**

FURTHER RESEARCH

- Investigation of other identified sites (Fuhrberger Feld and Lobau) with a whole new set of hydrogeological features.
- Molecular analysis of both groundwater and sediment microbial communities.

ACKNOWLEDGEMENTS

Funding: "Linking Redox-Cycling to Hydrogeology: Sedimentological Controls on the Capacity of Aquifers to Reduce Nitrate and other Dissolved Electron Acceptors (SeCuNDA)" project funded by the **Austrian Science Fund (FWF).** A collaborative project of the University of Kassel, the University of Tübingen, the University of Göttingen, Germany, and the University of Vienna. Special thanks to: Hubert Kraill, Grit Rasch, Mirjam Aubert, Gabriele Schwammel, Clemens Karwautz and the Groundwater Ecology Group