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Tidal-driven variations of nitrate concentrations in estuary sediments

ANNA LICHTSCHLAG[1], ALLISON SCHAAP[1] AND MORITZ HOLTAPPELS[2,3]

[1]National Oceanography Centre Southampton
[2]MARUM – Center for Marine Environmental Sciences
[3]Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research

Presenting Author: alic@noc.ac.uk

Situated at the interface between the land and the ocean, estuaries provide key ecosystem functions and services as they have high biotic diversity and production, can sequester large amounts of carbon and can mitigate land-based pollution. Estuaries also play an important role in nutrient cycling and knowledge about nitrate concentrations and their variation in sediments can be important to understand the recycling capacity and the carbon sequestration processes taking place in the estuary. However, the temporal changes that these highly dynamic environments experience often cannot be resolved with traditional sampling methods.

Here we present a novel approach that we used to understand the temporal variability of nitrate concentrations in the Itchen estuary, UK, using a spectrophotometric lab-on-chip sensor. With this sensor, nitrate concentrations were autonomously measured in the water column and at several sediment depth horizons over multiple tidal cycles on a sub-hourly timescale and results were compared to geochemical and physical properties of water column and sediment.

With our new approach we were able to demonstrate a strong benthic-pelagic coupling in the Itchen estuary. Nitrate concentrations in the water column were changing with tides, driven by dilution of high-nitrate river water by low-nitrate seawater during high tide. Sediments exhibited a strong vertical gradient of nitrate in the upper centimetre, with concentrations occasionally close to detection limit at 3 cm. This decrease will be caused by the combination of transport processes and microbial consumption of nitrate in the organic-rich silty to sandy sediment. However, with our novel in situ approach we demonstrated that also in the sediment, the nitrate concentrations were strongly varying with the tide (e.g. between 10 -50 μM at 1.5 cm and 0-30 μM at 2.5 cm).

In conclusion, our results indicate that Itchen estuary sediments are likely a substantial sink for nitrate. More broadly, this demonstrates that nutrient inventories in estuary sediments are likely to have a strong temporal variability due to the mixing of seawater with land-derived freshwater in these highly dynamic zones, and this may need to be taken into account when assessing the nutrient recycling capacity of estuaries.