

Biogeosciences Discuss., author comment AC1
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Reply on RC1

Justine Louis et al.

Author comment on "Linking sediment biodegradability with its origin in shallow coastal environments" by Justine Louis et al., Biogeosciences Discuss.,
<https://doi.org/10.5194/bg-2021-318-AC1>, 2022

Dear Wytze Lenstra,

We thank you for your constructive comments and corrections that we took into consideration to improve our revised manuscript.

Please find our answers to your main comments below.

- **The other factors that can control the benthic release of PO_4 and NH_4^+ , such as macrofaunal/microbial activities, should be more discussed**

As stated in the introduction (lines 44-47), the SOM biodegradability and nutrient release also depend on other factors such as the temperature, the terminal electron acceptor availability, and the microbial and macrofaunal activity and diversity. Nevertheless, the goal of our study was to separate the parameters related to SOM origin (=qualitative parameters) from the other sedimentary characteristics related to the chemical composition (C, N, P) and physical properties (=quantitative parameters) in order to assess their independent effects on the mineralization rates and benthic nutrient fluxes measured during the campaign. In order to link the NH_4^+ and PO_4 release with the sedimentary characteristics and the SOM origin, and to reduce other environmental variables such as temperature, light, overlying water nutrient concentrations, we have decided to conduct the core incubations for all sites under controlled temperature in the dark and by using nutrient-free artificial seawater as overlying water. All core incubations were done under the same ambient conditions. Nevertheless, as mentioned in the manuscript (lines 618 – 622), the microbial abundance/diversity as well as the bioturbation were not determined in our study. We assumed that these biological parameters could be significantly involved in the spatial variability of benthic nutrient fluxes, and therefore correspond to the residual part of the variance partitioning of nutrient fluxes that remains unexplained here. **More details about this assumption will be added to the revised manuscript, as you recommend:**

- "Through particle reworking and burrow ventilation by benthic macrofauna, a shift in redox conditions, a remobilization of burial OM, and a stimulation of solute exchanges at the interface can occur in the sediment (Graf and Rosenberg, 1997; Welsh, 2003; Kristensen et al., 2012). For example, Nizzoli et al. (2007) has shown a stimulation of

NH₄⁺ fluxes from all bioturbated sediment by the polychaete *Nereis* spp., whereas the bioturbation had site-specific effects on the PO₄ fluxes (sediment acts either as a source or sink of PO₄) which depends on, among other factors, the sediment composition, the burrow ventilation depth.”

- "We hypothesize that differences in microbial community structure, i.e diversity, may play a role in variations in SOM mineralization and nutrient recycling. Most literature focused on the effect of environmental variables shaping the microbial community structure (Ge et al., 2021 and references therein), but the impact of differences in microbial community composition on the sediment biodegradability of carbon remains little studied and thus speculative (Abell et al., 2013; Li et al., 2015). As Abell et al. (2013) showed, the bacterial community composition is related to the nature of the OM in estuarine systems, and their combination may lead to a shift in benthic nutrient fluxes.
- **More technical details about the sediment sampling and the measurements of benthic nutrient fluxes and mineralization rates need to be added, and information about redox conditions in bottom water and sediment is requested**

Please find below some technical details that will be added in the revised manuscript to improve its understanding:

Benthic nutrient flux measurements: As described in the Louis et al 2021, two 0.22 µm-filtered water samples were collected in the overlying water after 2h and 4h of incubation and stored at 4°C for less than 3 days until nutrient analysis. Nutrient-free artificial seawater was used for these incubations (lines 179-180). The water sample collected (5 ml) corresponded to 3 % of the total volume of the overlying water (150 ml). This collected volume was not replaced with new artificial seawater during the incubations, and the exact volume (145 ml for T2 and 140 ml for T4) was taken into account for the calculation of benthic nutrient fluxes. The core incubations allowed to preserve the redox conditions of the sediment and thus the term “realistic” mentioned in the manuscript (line 564) corresponds to “*in situ*”. Generally a low O₂ penetration in the sediment of few millimeters is observed in eutrophicated coastal areas. Vertical profiles of O₂ in the sediment collected by colleagues in the Trieux estuary, one of our sampling sites, confirm this statement. The sediments were depleted in oxygen below 2 mm vertical depth.

Before sediment sampling, no measurements of *in situ* bottom water redox conditions were done. The sediment cores of intertidal mudflats were collected at low tide. The core incubations carried out in our work allowed to assess the potential benthic NH₄⁺ and PO₄ fluxes mimicking the mudflat submerged during the rising tide by the oxygenated coastal water. The bottom water conditions can be considered oxic (based on temperature, salinity and tidal effect), sediment redox conditions were not determined for the 200 samples.

Surface sediment samples: For the sediment slurry incubation as well as for the characterization of surface sediment (physico-chemical composition, SOM origin), each sample was collected in the upper 5 cm sediment layer. This information will be added to 2.1 section.

Mineralization rate measurements: During the sediment slurry incubations, no measurements of oxygen were carried out. The mineralization rates were calculated from the measurement of CO₂ production. We consider that these incubations (time = 4h) were

carried out under oxic conditions over the 4 h incubation. These incubations consisted of 5 g of wet sediment mixed with 25 ml of artificial seawater in the glass flask of 145 ml total volume. It can be assumed based on previous work that the mineralization process was not oxygen-limited due to a large reservoir of O₂ in the headspace of flask ($V \approx 115$ ml) corresponding to 21 % of the air volume.

Under these conditions, we assumed that the presence of oxygen and homogenization of the sediments are optimal for SOM degradation (lines 539-543), and thus we were able to calculate the **optimal sediment reactivity, noted k**, from the measurements of mineralization rate and TOC content of sediment. A spatial variability of k was observed (0.8 to 11 y⁻¹ for 75 % of data) (lines 552-553). This approach has been used and described by Nicholls and Trimmer (2009) (<https://doi.org/10.3354/ame01285>).

▪ **A comparison between the benthic nutrient fluxes and mineralization rates is missing**

Even though a comparison would be interesting, we think a **direct** comparison between the mineralization rates and the benthic nutrient fluxes would be not appropriate as the methodology (slurry *versus* core incubations) and the redox conditions are different. Such differences can be illustrated by the fraction of their variances explained by the SOM origin: it was interesting to observe that the SOM origin had a significant effect on the NH₄⁺ and PO₄ fluxes, which was 1.5 and 5 fold higher than that determined by the other physico-chemical sediment parameters (e.g. porosity, TN and Org-P content), contrary to had been observed for the mineralization rates.

Sincerely yours, on behalf of all authors,

Justine Louis