

Biogeosciences Discuss., author comment AC3
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Reply on RC3

Justine Louis et al.

Author comment on "Linking sediment biodegradability with its origin in shallow coastal environments" by Justine Louis et al., Biogeosciences Discuss.,
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Dear reviewer,

We thank you for your constructive comments and corrections that we will consider to improve our revised manuscript. As you recommend, we plan to check and improve the manuscript by a native English speaker. Please find below our responses to your main comments:

- **More technical details about the measurements of benthic nutrient fluxes are requested**

We will add more detailed information regarding the benthic nutrient flux measurements in the revised manuscript as you suggest: Two 0.22 µm-filtered water samples were collected in the overlying water after 2h and 4h of incubation and stored at refrigerator temperature (4°C) for less than 3 days to the nutrient analysis by colorimetric method. The salinity of the artificial seawater used as overlying water for the core incubations was equivalent to that measured in the ambient bottom water collected in the Trieux estuary, one of our sampling sites, (salinity = 33.1) by our colleagues of the University of Bordeaux during the same period (april 2019). No oxygen measurement of the overlying water during the incubation was made, but it was well oxygenated by bubbling (lines 180 – 182). The core incubations carried out in our work allowed to assess the potential benthic NH_4^+ and PO_4 fluxes when the mudflat is submerged during the rising tide by the oxygenated coastal water. In addition, the mixing overlying water by bubbling allowed to prevent the build-up of concentration gradients at the sediment-water interface (lines 180 – 182). No measurement of oxygen penetration was done during the core incubations. Nevertheless, we know the vertical profiles of O_2 in the sediments collected in the Trieux estuary by our colleagues of the University of Bordeaux. The sediments were depleted in oxygen below 2 mm vertical depth. This confirms our statement mentioned lines 565 – 567: "In the eutrophicated coastal areas, as is the case in Brittany coast, the sediments are often constrained by the hypoxia, [...] a low O_2 penetration in the sediment of few millimeters (Middelburg and Levin, 2009)". Since the core incubations were rapidly carried out after sampling (lines 178 – 180) and during a short time (4h), we suggest that the redox conditions in the sediment cores correspond to that *in situ*.

- **Do the benthic nutrient fluxes reflect ambient *in situ* conditions?**

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. As you specify in your comments, a larger concentration gradient across the sediment-water interface can actually occur by using a nutrient-free overlying water. This is one of the reasons why we used the term "potential" for characterizing benthic nutrient fluxes. Nevertheless, we believe that the nutrient fluxes measured in our study can reflect the *in situ* fluxes. Firstly, the NH_4^+ and PO_4 concentrations in the coastal bottom water are not expected to be relatively high during the study period. In the Trieux estuary, the NH_4^+ and PO_4 concentrations in the bottom water were 1 and 0.1 μM respectively. Secondly, in the companion paper, we compared our results with previous studies carried out in Brittany and other European intertidal mudflats during the spring period, from either incubation in the dark or porewater nutrient profiles. Two of these were conducted respectively in the mouth of the Penzé river (Morlaix Bay) (Lerat et al., 1990) and in the Auray river (Andrieux et al., 2014), and allowed a direct comparison with our results. For the NH_4^+ fluxes, we presented values of $162 \pm 132 \mu\text{mol.m}^{-2}.\text{h}^{-1}$ in the Auray river and $25 \pm 16 \mu\text{mol.m}^{-2}.\text{h}^{-1}$ in the mouth of the Penzé river (sites #18 ad 19) against $206 \pm 47 \mu\text{mol.m}^{-2}.\text{h}^{-1}$ and $35 \pm 14 \mu\text{mol.m}^{-2}.\text{h}^{-1}$ respectively in the literature.

- **About the large part of the variance of the benthic NH_4^+ and PO_4 fluxes still unexplained: can the artificial conditions during the core incubations contribute to this unexplained part?**

Since one of the main objectives of our work was to link the spatial variability of benthic nutrient fluxes with that of sedimentary characteristics and SOM origin, the factors such as temperature and bottom water conditions were not considered here to facilitate comparison across sites. All core incubations were done under the same ambient conditions (see above answer). Therefore, the unexplained part of the variance partitioning of nutrient fluxes is likely not due to the artificial conditions during the core incubations. We assumed that the microbial abundance/diversity as well as the bioturbation would 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 (lines 618 – 622). More details about this assumption will be added to the revised manuscript:

- "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 NH_4^+ fluxes from all bioturbated sediment by the polychaete *Nereis* spp., whereas the bioturbation had site-specific effects on the PO_4 fluxes (sediment acts either as a source or sink of PO_4) 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 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."

- **Do the mineralization rates reflect ambient *in situ* conditions?**

Mineralization rate measurements were determined from the sediment slurry incubations under oxic conditions, and they were thus not considered here as the *in situ* mineralization rates. We assumed that the presence of oxygen as well as homogenization are optimal conditions to determine organic matter degradation and thus allowing calculation of the **optimal sediment reactivity, noted k** , from the measurements of mineralization rate and TOC content of sediment.

Sincerely yours, on behalf of all authors,

Justine Louis