

Biogeosciences Discuss., author comment AC2
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Reply on RC2

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-AC2>, 2022

Dear reviewer,

We thank you for your comments that we will consider to improve our revised manuscript. The revised manuscript will be corrected by a native English speaker. In the following section we respond to your different comments and questions:

- **Why did the methodology (regional scale, one-time sampling) used in the present study was appropriate to study the diversity of SOM origin/composition?**

As mentioned in the manuscript, most investigations on the spatial variation of the origin and composition of the SOM have been carried out so far at local scale, within a bay or along an estuary. There are only few studies on the regional scale (lines 79 – 82). Therefore, the first objective of this manuscript was to investigate the spatial variability of the origin and composition of the sedimentary organic matter (SOM) at the regional scale. The chosen study area was Brittany, particularly impacted by eutrophication due to the agricultural intensification and the urbanization of watersheds. We therefore expected to have a diversity of OM sources. This was confirmed in our study by combining bulk elemental, isotopic and chemical biomarkers analysis of surface sediment samples. Our results were from a one-time sampling during the spring, but the broad collection (200 samples on 45 sites) allowed to draw the regional variability of sediment characteristics at this study period. The large number of sediment samples also allowed to correctly run the statistical analysis, in order to link the sedimentary characteristics with the mineralization rates and benthic nutrient fluxes measured in our work.

- **A better connection between the two main parts in the discussion section (4.1 and 4.2) is requested**

As mentioned in the manuscript (lines 531 – 533), “after characterizing the SOM composition at the regional scale, the objective of this work was to quantify the relative significance of the SOM origin on the sediment reactivity, as well as to identify the SOM sources enabling the sediment to act as a nutrient source for the overlying water”. For a better understanding, we suggest to complete the opening paragraph of the second section 4.2 by reminding that “two statistical analysis were used: i) the variance

partitioning to quantify the variance proportion of nutrient fluxes and mineralization rates (response variables) independently explained by both the explanatory variables "SOM origin" and "physico-chemical composition", and ii) the canonical redundancy analysis (RDA) to assess the linear relationships between the explanatory variables and the response variables. **For the nutrient fluxes, with a significant part of variance explained by the SOM origin, the RDA allowed to assess which SOM sources can enhance the PO₄ and NH₄⁺ release. This could be illustrated using the spatial diversity of SOM origin previously drawn in the first part the discussion section".**

- **More information about anthropogenic inputs is requested**

As stated in the manuscript (lines 486 - 487), eutrophicated coastal systems, as Brittany coast, receive anthropogenic matter from urban discharges, agricultural and industrial activities impacting the SOM composition. It was expected to observe a mixture between natural (marine and/or terrestrial) and anthropogenic matter sources in our sediments. By using the $\delta^{15}\text{N}$ and lipid makers specific to anthropogenic matter (fecal matter, combustion products, oil and by-products), we allowed to assess how the impact of human activities on the surface sediment composition vary at the local and regional scale. We have well observed a discrimination between the north and south of the Brittany coast (lines 487 - 491): the sediment composition in the north sites seems to be more impacted by oils spills than the south sites, characterizing by an enrichment of crude oil markers. This likely results from the biggest oil spill that occurred off the north coast of the Brittany by the Amoco Cadiz (source: CEDRE). Conversely, the sediment composition in the south sites would be more impacted by an enrichment of petroleum products, which include products from the processing of crude oil at refineries. High values of $\delta^{15}\text{N}$ combined with high proportions of fecal markers in surface sediments allowed to trace sewage discharges and agricultural runoff. It was the case in the Vannes Estuary where our observations were consistent with the proximity of a WWTP (lines 501 - 508).

- **The role of the hydrodynamic conditions should be more considered in the discussion**

The diversity of the SOM composition results from potential sources of OM (related to algal production, land use, human activities ...) and also hydrodynamic conditions as mentioned in your comments. As discussed in the manuscript (lines 511 - 513), the hydrodynamic can control the spatial effect of sewage effluents on sediment composition. The gradient of $\delta^{15}\text{N}$ in surface sediments, that traced sewage-derived N, can be observed with a variable distance from the WWTP outfall according to coastal system (lines 506 - 511).

The addition of the following text in the discussion section about the potential additional role of hydrodynamic conditions on the SOM composition is proposed:

- In the sediments collected in the Goulven Bay where a significant proportion of macroalgal biomarkers was observed (Figure 4; lines 319 - 325): The sampling area was located in the upper part of the intertidal area of the Goulven Bay, which could be impacted by a high sedimentation rate. Under specific hydrodynamic conditions, a significant deposition of macroalgae could occur and fuel the SOM composition.
- In the sediments collected in the Rance Estuary, where high values of $\delta^{15}\text{N}$ as well as proportion of fecal markers were observed in the mid estuary of the Rance, which likely result from intensive agricultural activities in the watersheds (lines 515 - 521): The Rance Estuary is particular with the second largest operational tidal power station in the world built at the estuary's mouth (Rajae Rtimi et al., 2021). This could enhance the deposition of fine particles in the estuary, except upstream of the sluice gates and downstream of the turbines. The effect of agricultural activities on the molecular and isotopic signature of sediments could be more significant under these hydrodynamic conditions.

- **Is the term “estuary” appropriate to define the Rance and the Trieux?**

The sampling sites in our study were macrotidal mudflats located in Brittany bays and estuaries. We used the term “estuary” for the Rance and the Trieux, which is widely given in the scientific literature.

Examples:

- Rajae Rtimi et al. Hydrodynamics of a hyper-tidal estuary influenced by the world's second largest tidal power station (Rance estuary, France). *Estuarine, Coastal and Shelf Science*, Volume 250, 2021, <https://doi.org/10.1016/j.ecss.2020.107143>

In the present study, the sampling was done in the marine part of the Rance estuary (Figure 1 in Baron S et al (2017). doi: 10.3389/fmicb.2017.01637).

- Hugues Blanchet et al. Multiscale patterns in the diversity and organization of benthic intertidal fauna among French Atlantic estuaries. *Journal of Sea Research*, Volume 90, 2014, <https://doi.org/10.1016/j.seares.2014.02.014>.

In this publication, the authors specify that the Trieux estuary can be considered as a Ria system, and differs from coastal plain estuaries such as the Gironde, Loire.

- **The role of bioturbation and microbial abundance/diversity need to be more discussed**

In the revised manuscript, we will extent the discussion and add more details about the potential effect of microbial abundance/diversity as well as bioturbation on the benthic nutrient fluxes from the literature, which can involve in the large residual part of the variance analysis of benthic NH_4^+ and PO_4 fluxes (Lines 618 – 622):

- “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.

- **What about the biomarkers specific to bacteria?**

Bacterial biomarkers are included in the study. Four fatty acids specific to bacteria were identified: ante iso-pentadecanoic acid (aC15:0), iso-pentadecanoic acid (iC15:0), ante iso-pentadecanoic acid (aC17:0) et iso-pentadecanoic (iC17:0). The proportions and concentrations of these biomarkers were presented in the result section (lines 308 – 309) and the figure S1 in the supplementary material.

Sincerely yours, on behalf of all authors,

Justine Louis