We thank Reviewer 1 for taking time to give their thorough feedback and useful comments on our manuscript. The text in red indicates our response and the proposed modifications to the manuscript.

Reviewer 1:

The manuscript focuses on organic matter degradation rates in the Amsterdam harbor estuary according to strong anthropogenic influence through dredging activities, using spatial monitoring data and diverse incubation processes. The research is very interesting and meaningful for carbon cycle and greenhouse gas emission from the sediment in such impacted area. The topic of this manuscript fits well with the journal's scope, and the data collected highlighted a strong sampling effort and figures are of good quality.

However, it is important to address some issues in the manuscript before acceptance for publishment, here are some specific comments:

We sincerely thank the reviewer for their careful and constructive feedback during the first review of our manuscript.

Line 80-82: more details in which way shifting salinity affected CH4 are needed (even if discussed in discussion, see comment "line 675-677").

We understand the importance to explain shifting salinity affects CH_4, but Reviewer 2 suggests to avoid highlighting CH_4 in this sentence for a smoother transition. Thus, we propose that we delete "*particularly for CH_4*" in this sentence to keep this transition more general, but we explain the salinity impact on CH_4 in the following sentence. The revised text is as:

> *This can lead to a strong spatial variability in OM degradation pathways and carbon dynamics~~, particularly for CH_4~~ (Cao et al., 2021). For example, SO_4^{2-} (usually higher in saline seawater) inhibits CH_4 production via multiple mechanisms (e.g. anaerobic oxidation of CH_4), which can lead to lower CH_4 emissions (Lovley et al., 1987; Egger et al., 2018).*

Line 87: reference is missing.

Line 606: no () for the reference. Dauwe et al. (2001)

Line 642: Zander et al. (2022)

Corrections will be made in the revised manuscript.

Line 89-92: yes, but give examples of naturally and anthropogenically induced sediment disturbance.

We will add examples in the revised manuscript.

Line 111: avoid terms like "our". Here use "the". To be corrected throughout the manuscript (e. g. "our study" replaced by "the present study"…).

Line 139: "our"?

We will change this throughout the revised version of the manuscript.

Line 122-123: out of context here…

This is also related to the next comment raised by Reviewer 1. We propose to make the following modifications to this paragraph in the revised manuscript:

> *Understanding the processing of OM within estuaries takes on further importance because many estuarine systems are intensively altered by human activities (Arndt et al., 2013; Heckbert et al., 2012; Holligan and Reiners, 1992). To increase or maintain waterway navigability, dredging is ~~common sediment management~~ commonly practiced in many coastal regions and rivers worldwide. More than 600 million m^3 of dredged material is generated annually just in Western Europe, China, and the USA (Amar et al., 2021). ~~These anthropogenic perturbations expose buried sediment to an oxygenated environment, which is energetically favorable for OM degradation (LaRowe et al., 2020). The active sediment reworking on the Amazon shelf was reported to stimulate mineralization and decreased the sediment organic carbon content (Aller et al., 1996).~~ While the dredged sediments are often treated as waste and disposed at sea, there is a growing trend of reusing dredged sediments on land, such as beach nourishment, habitat restoration, and land reclamation (Brils et al., 2014), aiming to valorize these massive amounts of dredged materials. However, perturbations during dredging and the following management practices pose a great unknown in the fate of the large amount of organic carbon stored in these sediments, with oxygen exposure potentially leading to a substantial increase of carbon release (LaRowe et al., 2020). Given the needs of sediment dredging and the sustainable management of these materials (van de Velde et al., 2018), it is of great importance to understand to what extent anthropogenic sediment perturbations may potentially affect OM processing and carbon emissions from estuarine sediments.*

Line 138-139: representative of dredged sediment conditioned on land? Is this conditioning the major process for dredged sediment? Line 151 mentioned sediment relocated in the sea. More explanations are needed to justify the choice of these open-air incubations.

We appreciate the reviewer's comments regarding the rationale of the open-air incubations. We will add detailed explanations to justify the choice of open-air incubations in the revised manuscript.

Indeed, as mentioned in Line151, most of the dredged sediments are currently relocated to the North Sea, and the whole-core incubations were performed under the water. However, long-term incubation experiments with submerged sediments (including slurries) may suffer from kinetic limitations in oxygen supply, potentially introducing artefacts in estimating degradation rates. Open-air incubations with optimally wetted sediments, however, avoid these kinetic limitations, allowing us to better quantify the oxic degradation potential.

Another reason is linked to the previous comment of Reviewer 1 (see above). There is a growing trend and need to valorize dredged sediment on land (e.g. land reclamation, habitat restoration, beach nourishment) rather than directly disposing of these materials at sea. We recognize that the choice of open-air incubation in this study is a simplification of those on-land applications and may not fully represent the reality, but the findings of open-air experiments are still insightful in estimating the carbon emission potential of dredged sediments when exposed to oxygen on land or in oxygenated aquatic environments.

Line 151-152: The rates shown are per year?

Yes.

Line 155-156: how many cores replicates for each location?

Bulk sediments were collected using one sediment core (Line 155–156), while triplicate cores were used for the intact incubation (Line 241). Clarification will be added.

Line 242-243: Even evident for the author, precise the reason to have 20 cm of overlying water.

The reason to keep this amount of overlaying water is to ensure adequate solute concentration changes during incubation while minimizing the sampling impacts of the overlaying water sampling. Each time, we sampled 30-mL overlaying water while the same volume of site water was automatically refilled from a reservoir. In this way, we keep a relatively small fraction (i.e. 2.3%) of water replacement at each sampling time. We will add an explanation in the revised manuscript.

Line 285: Why 37 days incubation period were chosen?

Thanks for pointing this out. This length of incubation time was decided during the progress of the incubation experiments, based on the observed carbon dynamics. The carbon emission rates on day 23, 30 and 37 were much smaller and more stable compared to the rates measured at the beginning (Fig. 6). These data points allow us to extrapolate the percentage of degradable TOC from day 37 onwards (Fig. 7), and the carbon release from day 37 onwards is likely associated with the slow-carbon pool, which is relatively stable. A prolonged incubation is unlikely to add substantial significance to the data interpretation. An explanation will be added.

Line 581: Short range of these different values is needed.

This will be added.

Line 675-677: include the concept of SMTZ (sulfate-methane transition zone)

We will include it in the revised manuscript.

Line 681: “depending on”

We will correct it.

Line 687: I don't know if the conclusion needs to be so precise about the results of the study…

Thank you for pointing this out. We will revise the conclusion by removing unnecessary details.

Additional comments: where are the dredging locations on Fig. 1? Dredging affects the upstream and downstream areas of the estuary in a similar way?

Dredging is performed throughout the port area in Fig. 1, but there are more dredging activities at the marine side than at the riverine side. Information will be added to section 2.1.

Please give some details on this subject. What would be the consequences of such an imbalance, according to quantity of sediment dredged in each zone?

We appreciate the reviewer mentioning this point. Indeed, we did not explore the impact of this aspect in the manuscript. We will include this discussion in the revised manuscript. More dredging activities at the marine site (115) might contribute to its lower TOC content (Fig. 2a). However, higher fractions of labile OM (Fig. 7) and faster degradation rates (Fig. 5, 6) in marine sediments suggest that the OM quality/degradability in the investigated area is mainly controlled by the OM input sources and the rapid sedimentation, while dredging, although enhancing degradation of labile OM, is not the determining factor of OM quality/degradability.

What about the sediment relocated in the sea in terms of potential carbon mineralization processes?

We appreciate this consideration. In the Port of Rotterdam (PoR), the current practice of relocating dredged sediment to the North Sea may enhance the OM mineralization rate (3.4–7.6 times) similarly like open-air experiments due to exposure to oxygenated seawater. However, the degree of mineralization is affected by the sediment dynamics after disposal (i.e. sediment resuspension might result in more extensive mineralization, while rapid sediment burial, which limits oxygen exposure, can better preserve organic carbon). We will discuss this in the revised manuscript.

And finally CO2/CH4 effluxes toward the atmosphere?

Thank you for the inspiration, but we feel this is beyond the scope of this manuscript. This study pivots on perturbation impacts on OM mineralization coupled to OM composition. While the eventual outgassing is not the focus here, the measured carbon release from undisturbed and disturbed sediments can potentially enter the atmosphere. We will briefly mention this in the revised manuscript as a possible direction for future research.

References

Aller, R. C., Blair, N. E., Xia, Q., and Rude, P. D.: Remineralization rates, recycling, and storage of carbon in Amazon shelf sediments, Cont Shelf Res, 16, 753–786, https://doi.org/10.1016/0278-4343(95)00046-1, 1996.

Amar, M., Benzerzour, M., Kleib, J., and Abriak, N. E.: From dredged sediment to supplementary cementitious material: characterization, treatment, and reuse, International Journal of Sediment Research, 36, 92–109, https://doi.org/10.1016/j.ijsrc.2020.06.002, 2021.

Arndt, S., Jørgensen, B. B., LaRowe, D. E., Middelburg, J. J., Pancost, R. D., and Regnier, P.: Quantifying the degradation of organic matter in marine sediments: A review and synthesis, Earth Sci Rev, 123, 53–86, https://doi.org/10.1016/j.earscirev.2013.02.008, 2013.

Brils, J., de Boer, P., Mulder, J., and de Boer, E.: Reuse of dredged material as a way to tackle societal challenges, J Soils Sediments, 14, 1638–1641, https://doi.org/10.1007/s11368-014-0918-0, 2014.

Cao, C., Cai, F., Qi, H., Zhao, S., and Wu, C.: Differences in the sulfate–methane transitional zone in coastal pockmarks in various sedimentary environments, Water (Switzerland), 13, 1–18, https://doi.org/10.3390/w13010068, 2021.

Heckbert, S., Costanza, R., Poloczanska, E. S., and Richardson, A. J.: Climate Regulation as a Service from Estuarine and Coastal Ecosystems, Elsevier Inc., 199–216 pp., https://doi.org/10.1016/B978-0-12-374711-2.01211-0, 2012.

Holligan, P. M. and Reiners, W. A.: Predicting the Responses of the Coastal Zone to Global Change, Adv Ecol Res, 22, 211–255, https://doi.org/10.1016/S0065-2504(08)60137-3, 1992.

LaRowe, D. E., Arndt, S., Bradley, J. A., Estes, E. R., Hoarfrost, A., Lang, S. Q., Lloyd, K. G., Mahmoudi, N., Orsi, W. D., Shah Walter, S. R., Steen, A. D., and Zhao, R.: The fate of organic carbon in marine sediments - New insights from recent data and analysis, Earth Sci Rev, 204, 103146, https://doi.org/10.1016/j.earscirev.2020.103146, 2020.

van de Velde, S., van Lancker, V., Hidalgo-Martinez, S., Berelson, W. M., and Meysman, F. J. R.: Anthropogenic disturbance keeps the coastal seafloor biogeochemistry in a transient state, Sci Rep, 8, 1–10, https://doi.org/10.1038/s41598-018-23925-y, 2018.