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 of explaining how shifts in salinity may affect CH_4, but in contrast Reviewer #2 suggests to avoid highlighting CH_4 here for a smoother transition. We propose deleting here "*particularly for CH_4*" to keep the transition more general. We will explain the salinity impact on CH_4 in the following sentence. The proposed revised text:

> *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-} (which covaries with salinity) inhibits CH_4 release via multiple mechanisms (e.g. anaerobic oxidation of CH_4; 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:

> *Understanding the processing of OM within estuaries takes on further importance because estuarine systems are often 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 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 of the dredged sediments pose an important unknow in the fate of the organic carbon stored in these sediments, with oxygen exposure potentially leading to enhanced carbon remineralization (LaRowe et al., 2020). Given the need for sediment dredging and sustainable management of these materials (van de Velde et al., 2018), it is of great importance to understand to what extent anthropogenic sediment perturbations can 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 accordingly whole-core incubations were performed under water. However, these long-term incubation experiments with submerged sediments (including slurries) may suffer from limited oxygen supply, potentially introducing artefacts in estimating degradation rates. Open-air incubations with optimally wetted sediments, however, avoid such limitations, allowing us to better quantify the oxic degradation potential.

Another reason for performing open-air incubation is linked to the previous comment of Reviewer #1 (see above). Sediment is increasingly reused in (subaerial) applications rather than disposed at sea. Although the open-air incubations in this study are a simplification of on-land applications, findings are still insightful for 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 a single sediment core (Line 155–156), while triplicate cores were used for the incubation of intact sediments (Line 241). Clarification will be added.

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

In whole-core sediment incubations, the top 10-20 cm is commonly used because this is the primary zone of diagenesis; an equivalent volume is overlying water is used to (1) avoid rapid depletion/accumulation of dissolved reactants or reactions product to the extent that it affects biogeochemical processes and (2) avoid a large percentage of water exchange (here, 30 mL water, equivalent to 2.3% of overlaying water) when taking discrete samples. We will add an explanation to the revised manuscript.

Line 285: Why 37 days incubation period were chosen?

Thanks for pointing this out. The duration for the incubation was based on the progress of the incubation experiments, as observed in the carbon turnover. The carbon emission rates on day 23, 30 and 37 were much smaller and stable compared to the rates measured early during the experiments (Fig. 6). These data points allow us to extrapolate degradable TOC percentages reliably from 30 days onwards, with 37 days being used as extra check (Fig. 7). The slow carbon from 30 days onward is likely associated with the slow-carbon pool, which is relatively stable. A prolonged incubation is unlikely to substantially alter 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 the SMTZ concept in the revised manuscript.

Line 681: “depending on”

Correction will be made.

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 indicated in Fig. 1, albeit with more dredging activities at the marine side compared to the riverine side. This 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 acknowledge the reviewer for mentioning this point. We did not yet explore the impact of imbalanced dredging activities across the harbor on sediment OM characteristics and the corresponding implications on carbon release. We will include this to the discussion in the revised manuscript. More dredging activities at the marine site (115) might contribute to the generally 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 source of the OM and rapid sedimentation. Dredging, although likely enhancing degradation of labile OM, is hence not controlling 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 OM mineralization rate due to enhanced exposure to oxygenated seawater during dredging and redeposition. However, the degree of remineralization is affected by the sediment dynamics after disposal (e.g. sediment resuspension might result in more extensive mineralization, while rapid sediment burial, which limits oxygen exposure, likely enhances organic carbon preservation). We will discuss these aspects in the revised manuscript.

And finally CO2/CH4 effluxes toward the atmosphere?
Ultimately the effluxes to the atmosphere is what matters and we hence appreciated this comment. However, gas exchange between the sea surface and the atmosphere is a research subject in itself and beyond the scope of this manuscript. 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.