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Hydrology and Earth System Sciences Discussions



# *Interactive comment on* "Assessing the biodegradability of terrestrially-derived organicmatter in Scottish sea loch sediments" *by* P. S. Loh et al.

**P. S. Loh et al.**

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General comments: 1) Their relative importance for OM cycling remains unclear. I am thus recommending more quantitative information about the origin and fate of OM in sea loch environments. The origin and fate of OM are not discussed in this study, because these are discussed in Loh et al. (2008). This is explained in section 4.1, the last sentence of the second paragraph: The importance of terrestrial OM fuelling the biogeochemical cycling of carbon in the lochs was explained in better details by Loh et al. (2008).

The use of oxygen uptake rates as a measure of OM degradation is standard the field

of (marine) sediment biogeochemistry and is, thus, not novel. In addition, possible shortcomings of this approach have long been identified (a significant fraction of the oxygen consumption can be channelled in the re-oxidation of reduced products) and the authors currently do not provide any strong, comprehensive, evidence that these alternative oxygen consuming pathways (from all possible reduced redox species) are negligible in their system. The authors claim instead that the variability in the uptake rates is due to the amount of (terrestrial) OM. However, this seems to be contradicted by the absence of obvious relationship between oxygen uptake and % labile OM. - Yes, the shortcomings of this approach have been identified. This is now mentioned in section 1 (Introduction), the last sentences of the first paragraph: However, there are some shortcomings of this approach. The oxygen uptake could also be due to the oxidation of reduced species formed during anaerobic OM degradation (Elsgaard and Jorgensen, 1992; Overnell et al., 1995). - Yes, the oxygen uptake rates could be due to reduced species. This is mentioned in the first paragraph of section 4.2.1 (the last sentence). - No, based on the results in this study, we could not provide evidence that these alternative oxygen consuming pathways are negligible. We can only use evidence by Overnell et al. (1995) that sulphate reduction contributes 7-8% of the oxygen uptake rate (Section 4.2.1, last sentence of the first paragraph). - We said that the variability in the rates is due to the amount of terrestrial OM. This is because the most significant trend observed is a decrease in the oxygen uptake rates from the head to mouth of the loch. Besides, lignin, OM and OC all decreased further down the lochs. These parameters: lignin, OM and OC also have strong correlations among one another. Hence terrestrial OM is the most important factor causing the highest oxygen uptake rates at the head of Loch Creran.

To broaden the scope of this ms., the values of oxygen consumption, OM contents and reactivity in the present study should also be compared with values from other terrestrial and marine ecosystems. The values of oxygen uptake rates found in previous studies are now given in the first paragraph of Section 4.2.1.



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Finally an attempt at quantifying the contribution of terrestrial OM to the overall bioegeochemical cycling (a very vague objective identified by the authors). This sentence is now deleted because determination of the contribution of terrestrial OM to the biogeochemical cycling was not explained in great detail in this paper; this is more relevant to the work of Loh et al. (2008), where it is explained in more relevant detail.

2) The authors should however try to combine the information from the indicators to analyze, in quantitative terms, the fate of OM in the sea lochs. In order to prevent further confusion, any mention of the determination of the fate of OM is now deleted. Besides, this was not discussed in detail in this study. In this study, we now concentrate in the discussion of the use of the proxies to determine the biodegradability of the sedimentary OM.

What is the contribution from the various terrestrial OM sources, the marine OM, how much is deposited, how much is decomposed during transport, etc. .. The authors are currently preparing a manuscript drawing together the carbon budget for Loch Creran: we intend to include this information in that forum.

The results about the lignin contents and behaviour are interesting. However, after reading through the ms., the fate of this specific compounds (in terms of in-situ degradation) still remains unclear. This study concentrates on discussing the use of various parameters as the proxies to determine the biodegradability of the sedimentary OM. The ‘fate’ of lignin and terrestrial OM was more relevant to Loh et al. (2008), where it was discussed in appropriate detail.

Specific comments:

Introduction: Line 23 p 4006: Meaning of: corrected Line 8 p 4007: Yes, it is. So this is now changed to OM mineralization by aerobic pathway, the oxygen being supplied by the activity of burrowing organisms. Line 10 p 4007: I do not agree .. : this sentence is now deleted. Line 24-30 p 4007: This information is too technical for an introduction. This information is now in section 2.3.2 Lignin analysis. Line 12 p 4008: Which study?



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.. the study showed .. is now corrected to ‘the author’ showed .. Line 15 p 4008: sediment biodegradability changed to OM biodegradability. Line 17-19 p 4008: Clarify this sentence. Implies the presence of non-living material ... This is now explained as: Increases in the OC/N ratio also implies the presence of plant materials which has higher proportion of C to N than marine OM (Pocklington, 1976), ... Line 19 p 4008: There are numerous observations of increasing C/N ratio during early diagenesis. The relationship between decreasing C/N ratios and diagenesis is thus misleading. Hence in this study, we also stated the need of comparison of the various proxies, for example, decrease of C/N ratio versus increase Rp values could indicate OM degradation. **Line 23 p 4008: this is not a clear objective. This is now deleted. The objective of this study remains to be the determination of the use of the proxies to indicate sediment biodegradability.

Materials and Methods: P 4009: mean freshwater input into Loch Creran is 286 x 106 m3 yr-1 and the freshwater input into Loch Etive is 3037.5 x 106 m3 yr-1 (Edwards and Sharples, 1986). This is now corrected. Why not the residence time for both lochs? The mean water residence time in Loch Etive is 16 months and in Loch Creran three days. No information is provided about the fate of solid particles in the sea lochs. No, but Loh et al. (2008) discussed about the fate of terrestrial OM in the water column, .

Line 12 p 4011: What are the implications of the chosen timescale for the oxygen uptake rate experiments (24 hours is a very short period)? I am sure there is no definite timescale for this test. Parkes and Buckingham (1986) had used 3 to 6 hours. At first we tried 6 hours, but we found that this timescale was too short (the uptake rates obtained were too low). We found that 24 hours was just nice to determine the rate.

**On the basis of these rates and labile OM contents, could any kinetic rate constant for OM degradation be extracted? The kinetic rate constant for OM degradation is not determined as the authors wish to concentrate on the use of these proxies to determine the sediment biodegradability.



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Isotope analysis p 4013 & 4015: the isotope measurements are not used at all to support any argument in the discussion. The δ13C values are used (in Section 4.1) to support the argument that terrestrial OM decreased from the head to mouth of the loch.

Results: Yields results p 4014: Are these results already discussed in Loh et al., 2008 (ref indicated in Table 2)? In Loh et al. (2008), these results were used to discuss the fate of terrestrial OM in the water column, upon deposition onto the surface sediments and in the subsurface sediments. In this paper, however, these results are used to determine the use of these proxies to serve as indicator for the biodegradability of the sedimentary OM. Line 17-19 p 4014: The two sentences state similar facts. One of the sentences is now deleted. Line 21 p 4014: Value for LC6 0.45. Line 24 p 4014: corrected to range from 0.70 to 0.71. Oxygen uptake rates, p 4015: The differences at LC1 seem minor to me (rather than significant): Yes, but there are some months which showed significant differences (Table 3). This is now mentioned in section 3.2.1 as: The significant differences (ANOVA: $p<0.05$) of the rates are given in Table 3.

At LC1, the seasonal variability is attributed to the microbial degradation of fresh terrestrial OM. This does not explain why there are seasonal variations: Is it due to temperature effects that stimulate OM decomposition during the summer months or is it due to the sudden input of easily degradable OM? - Yes the seasonal variability is most probably due to microbial degradation of OM, and yes it is closely related to the increase of temperature during the summer months (hence seasonal variability). This is not due to the sudden input of easily degradable OM as there are no significant correlations (regression analyses: $p>0.05$) between oxygen uptake rates with lignin, OM and OC at LC1.

I would suspect that even if OM material remains the same, the degradation rate would increase due to the physiological effect of temperature on bacterial activity. But then how would you explain the higher rates in December at LC5 when temperature is lowest? Something should be said about the small scale sampling heterogeneities. - This



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is now explained in the third paragraph of section 4.2.1 as: This fluctuation could be because LC5 is located in a sheltered area which accumulated more terrestrial OM and OC (Tables 2 and 4) which in turn increased the rate of OM degradation. Santos et al. (1994) also recognized small scale sampling heterogeneities on the spatial variability in the sedimentary organic matter quality and quantity in marine sediments..

Line 2 P 4016: corrected to no significant seasonal trend Line 5-6 p 4016: This qualitative statement is obvious to me .. This sentence is now deleted, because what happens to the OM is discussed in Loh et al. (2008). Line 25-27: Clarify this statement. These sentences are now deleted (based also on the comments from Reviewer 2).

Discussion: P 4017: What could be the other sources of terrestrial OM to the lochs? Without clear identification of alternative sources, the statement about the origin of terrestrial OM seems trivial. What are the source and composition of the non-lignin material (marine OM only?). In addition, I recommend plotting results of the correlation analyses. The other sources of terrestrial OM to the lochs could be from other smaller rivers, but based on our results, the major sources are the main rivers. Based on our results (decreased of lignin materials and increase of δ13C values from the head to mouth of the lochs), the sources of marine OM are from Firth of Lorne. The correlation results are now given in Table 5.

Line 1 p 4017: If this is true between Camas and RE6, why is there no decrease between RE2 and RE6, two stations which are far apart. If there was no River Awe draining into RE6, most probably the OM contents in RE6 would be significantly lower than that in RE2. The high OM content in RE6 is most probably due to the input of materials from the River Awe, which drains into the loch between RE5 and RE6.

Line 20 p 4018: corrected to .. than at other locations

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