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Biogeosciences Discussions

Interactive comment on "Does ocean acidification induce an upward flux of marineaggregates?" *by* X. Mari

X. Mari

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This paper describes experimental work on the effect of pH on TEP formation, aggregation and carbon flux. It is found that more and larger TEP are formed abiotically as the pH is decreased by 0.2, 0.4 and 0.8 units below ambient (pH = 8.16). This increase is not linear, but large for the first decrease (by 0.2 units) and much smaller thereafter. The increase in total and average TEP volume is thought to be due to differences in the gel structure, rather than in the amount of TEP per se. Although, possibly a lower pH will change the equilibrium between TEP-precursor and TEP in the direction of TEP. This second option was not mentioned.

Author Reply: I did not mention this option because in order to change the equilibrium between TEP-precursors and TEP in the direction of TEP, the stickiness of TEP has to increase. This mechanism is somewhat contradictory with the observed decrease in

the aggregation of TEP with beads, unless the intraspecific (i.e., TEP-TEP) stickiness is enhanced while the interspecific (i.e., TEP-beads) stickiness is reduced. I have added a short comment in the revised version in order to acknowledge for that possibility.

Furthermore it was found that aggregation of TEP with beads decreases appreciably with decreasing pH. Again a large change is found for the initial reduction in pH of 0.2 units with smaller changes observed when the pH is lowered further. The data on settling is interpreted to indicate that the average ascending velocity of TEP and beads increases linearly with decreasing pH.

Although this data is clearly not mimicking natural conditions, it very nicely shows potential effects of ocean acidification on the abiotic formation of TEP and its stickiness. These insights are used to discuss mechanisms and how ocean acidification can lead to a decrease in the biological pumping and thus to a positive feed back of ocean acidification.

This is an important topic to discuss, especially as the opposite trends have just been postulated from a mesocosm experiment (Riebesell & al. 2007). The controversy between the two opposing hypothesis (positive or negative feed back of the biological pump) can not be resolved with the information available, as both studies are not directly comparable, and as both studies only take certain aspects into account. But this controversy highlights the need for further investigations and suggests potentially important mechanisms to investigate in more detail!

The pH changes investigated (pH 7.2 to 8.2) lie in the range which can be found in situ in today's ocean. But as the authors point out, natural sinking aggregates are usually laden with heavier particles and investigations of the SML are rare. And TEP have been found to accumulate in the SML (Wurl & Holmes 2008) and may do so more than we are aware of. So our field knowledge does not contradict the findings of this investigation.

Author Reply: The investigations of the SML are very scarce and I did not find direct

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evidence that TEP were actually accumulating in the SML when I wrote the submitted manuscript. I did not know of this study by Wurl and Holmes (2008). I find it very interesting and particularly timely for two reasons. First, it shows that TEP indeed accumulate in the SML. Secondly, that the TEP fraction in the SML is higher in the estuarine systems. This second point is particularly interesting because estuaries are known to experience strong pH variations. I refer to this study in the revised version of the manuscript.

The interpretation of the settling experiment (Fig.3) is clearly difficult. Although the difference between control and pH reduced treatments is significant, the budgets within each treatment don't close. That is unfortunate.

Author Reply: I agree. I could not close the budget for two reasons: because I did not sample the middle layer and the SML. However, I think main solution lies in the SML, which could not be sampled considering the experimental conditions. I am aware of this limitation, and this is the reason why I am very cautious when concluding. I agree that future work should really focus on the dynamic of the SML formation. However, as I replied to Referee #1, the hypothesis that ascending particles were accumulating in the SML cannot be proved otherwise than by studying the dynamic of SML formation, however this hypothesis is only needed to explain the fact that while particles were leaving the bottom layer they were not recovered in the surface layer. Actually, testing this hypothesis is not required to validate the import rate of particles in the bottom layer (i.e., settling velocity) or of the export rate of particles from the bottom layer (i.e., ascending velocity). I do not think it is crucial to study the middle layer in order to estimate the velocity at which TEP and beads were leaving (via upward transport) or reaching (via downward transport) the bottom layer. Since the particles that were collected in the bottom layer could not be missed (like it is the case in the surface layer), variations of particles' concentration in the bottom layer gives robust estimates of the import rate of particles in this layer (i.e., settling velocity) or of the export rate of particles from this layer (i.e., ascending velocity). The only alternative way settling and

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ascending velocities could have been misestimated when derived from the variations of particles' concentration in the bottom layer, is if particles were accumulating in the middle of the chambers. Such a process is highly unlikely in a water column of less than 9 cm height and without a density gradient. In other words, I agree that it would have been useful to have the concentration of particles in the middle layer and in the SML in order to close the budget and to demonstrate that the SML is indeed a sink for ascending particles, but I argue that changes in the concentration of particles in the bottom layer are sufficient to determine the direction of vertical flux and to give estimates of settling and ascending velocities.

The explanation that the SML layer was not sampled adequately is likely correct, but other explanations are possible. Bacterial degradation of TEP for example could have reduced the amount of TEP in both the top and bottom layer.

Author Reply: Since the solutions were filtered through 0.2 μm, bacteria were not present in the settling chambers and, thus, the amount of TEP could not be altered by bacterial degradation.

Loss to the container walls, without prior transport to the SML is another potential reason for loss of TEP and maybe beads.

Author Reply: Since there is no thermal gradient inside the settling chambers (see M&M) horizontal convection can be considered minimal and, thus, although possible horizontal transport and subsequent attachment to the walls is probably not a significant loss factor. This comment has been added in the revised version.

Future experiments clearly need to sample the SML and the middle layer so as to close the budget. The difficulty in interpretation of this data contributes a certain uncertainty to the proposed ascending velocity as a function of TEP. However, the exercise demonstrates well the potential impact of the proposed effects. Thus this paper should serve well to initiate a serious discussion on the topic of pH effects on the soft tissue carbon pump (the calcium carbonate carbon part of the biological pump is not discussed).

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The MS is well written and figures are clear. The text in figure three is extremely small.

Author Reply: The font sizes are the same for all figures in the original files. The font sizes' difference between the figures is most likely due to the automatic compiling procedure. If requested, I will change the font size for figure 3.

Where TEP and beads always associated (including in figure 3), or did some beads remain unattached to TEP and sediment individually. The amount of unattached TEP and beads would impact the expected sedimentation.

Author Reply: Some beads and some TEP were 'unattached'. TEP and beads concentrations in figure 3 are total concentrations, i.e., the concentrations of TEP and beads associated or not. The fact that some TEP and some beads were not observed as associated particles does not mean that they were not associated prior sampling. Actually, the sampling procedure inside the settling chambers (siphoning) certainly detached some beads from TEP and altered the TEP-beads relationship, but this mechanism is not easily quantifiable. Anyway, these settling experiments do not allow determining the mechanism of transport, only to show the result of that transport (i.e., variations of particles' concentration within a given layer).

page 1637 line 18: take out "and"

Author Reply: This sentence has been corrected accordingly.

Interactive comment on Biogeosciences Discuss., 5, 1631, 2008.