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Discussions

Interactive comment on "Simultaneous quantification of in situ infaunal activity and pore-water metal concentrations: establishment of benthic ecosystem process-function relations" *by* L. R. Teal et al.

Anonymous Referee #2

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In this study Teal et al. investigated sediment reworking rates and the distribution pore-water metals in-situ in bioturbated sediments. They use state of the art techniques (f-SPI and DGT) to measure these parameters simultaneously. The time-lapse approach of fluorescence particle profile imaging allowed them to get insights in the temporal dynamics of particle reworking rates and link these to the distribution of Fe and Mn in the pore-water. The manuscript is well written and structured.

I like the study, and I agree that such in-situ measurements are crucial to relate findings from laboratory experiments to the real world. In this context the present study is a very

valid contribution to research focusing on effects of bioturbation on biogeochemical processes in benthic systems and fits into the scope of Biogeosciences.

While the experimental study is sound, I have some major problems in the way how this study is introduced and discussed. While a lot of text is spend on describing that the interplay between organisms and the environment is complex (which results in text constructions like "context dependent effects of inter- and intra- specific behaviour and integrating species-environment interactions") there are hardly any concrete hypotheses that focus on the core of the study (e.g., why is trace metal cycling tackled other than that there are techniques to do it). The fact that particle and pore-water mixing take place on very different time scales is true (e.g., Berg et al. MEPS 2001) but given the time-integrated and space-integrated approach of DGT used here, I do not see that this study yields new insights into the coupling between particle movement and fluid flow. In fact, the combination of high temporal imaging of "slow" particle reworking and time-integrated and horizontal averaged measurements of "fast" solute transport somehow contradicts the aim of the study, i.e., measurements at appropriate spatial and temporal scales. Recent studies by Stahl et al. (2012) and Zhu and Aller (2012) indicate the very heterogeneous (and to some extent the dynamic) distribution of pore-water metals in bioturbated sediments and their findings would be helpful in discussing the results of this study. Specifically, I would like to see a much more detailed discussion of how bioturbation, including bioirrigation, may affect the distribution of Fe and Mn, under which conditions are they dissolved in the pore-water (and accumulate in DGT) or participate as particles, to what extent is their mobilization affected by oxygen, nitrate or sulfide etc. The study by Volkenborn et al. (2012) indicates the oscillatory nature of bioturbated sediment, so what would be the impact on e.g. Fe and Mn distributions, redox state and transport? The authors state that they investigate trace metal cycling as a proxy of ecosystem functioning, but without a more detailed discussion of the underlying processes that may have contributed to the observed and modeled Fe and Mn profiles this study investigates pore-water metal distribution and not on their cycling. Consequently, I have strong objections is using Fe and Mn distributions as an

example of “ecosystem functioning”.

Indeed, bioturbation is complex and involves ecological, physiological, biogeochemical and physical aspects. To test if the use of “multiple technologies provide additional insights” is trivial, and I strongly disagree that “multiple technologies are seldom used together”. I think that especially research on bioturbation has some very nice examples of interdisciplinary approaches and methodological integration.

The introduction to some extent fails to introduce the core of this study. The same introduction could be used to introduce any other study as it largely dwells in very broad aspects on benthic ecosystem functioning and its complexity. E.g., what is the contribution of trace metal dynamics to organic mineralization processes? How is metal redox cycling affected by the presence of other chemical species? What are the spatial and temporal scales on which we need to tackle sediment reworking and bioirrigation?

Results: It would be useful to describe the study site a bit more in detail with respect to the sediment characteristics. Are there any data on grain size, organic content, permeability, topographic features (ripples, mounds etc)? Is it a diffusion or advective dominated system? If such data do not exist, at least a statement about the general character of the site (muddy or sandy) would be useful. The authors state several times that the outcome of bioturbation is context dependent. Sediment type is one, if not the most important context. So it would be useful to have some idea about the setting at the site.

On the other hand information about changes in water depth due to tides is largely unnecessary. I guess the authors mention these changes in water depth because they discuss tidal flushing as a mechanism that may have affected pore water metal distributions. Pore-water advection in permeable sediment is driven by pressure gradients. Can the slow raise and fall in water level really affect pore-water flow? How strong are tidal currents close to the seafloor? What about wave action? Again, more information about the study site character would be useful.

Table1: If there was 1 individual in one of the six 100 cm2 cores this would correspond to an average abundance of 16.6 ind m-2. So how is it possible a minimum abundance on 5.31 was found for several species? Please clarify. Also, on page 8550 Line 26 the authors state that Amphiura and Terebellidae were consistently found across samples. Being present in three out of six samples is not consistent.

Page 8551 Line 8: does this not also, and more importantly, suggest spatial differences in species composition? And thus a problem of insufficient replication, especially if the aim is to derive implications for processes on larger spatial scales?

Page 8552 Line 2: construction of a deep burrow does not really sound appropriate, maybe better 2 cm deep mixing (just as on page 8551 line 15)?

Discussion: Page 8556 L 15-20 To link particle and pore water mixing, DGT is not really appropriate, because it time-integrates and horizontally averages pore-water metal distributions. Insights from microsensors and planar optode studies should be discussed (Wenzhoefer and Glud 2004; Timmermann et al. 2006; Stahl et al. 2012; Zhu and Aller 2012; Volkenborn et al. 2012). While DGT is an elegant way to characterize pore-water solute profiles in-situ, it does not allow characterizing the spatial-temporal dynamics which are characteristic for bioturbated sediments. In a strict sense, the present study is an example of measurements on an inappropriate spatio-temporal scale (Page 8544 L 23ff) to link fluid flow and particle movement. A broader discussion of ways to tackle these time scales would be useful.

Overall I like the study, the in-situ approach, and the methodology, but from my point of view this paper could gain a lot if the introduction would be more focused towards the aim of this study and expand on metal biogeochemistry. The discussion of results should include some of the shortcomings of time-integrated approaches to study pore water dynamics and integrate some of the recent literature on the dynamics and heterogeneity of pore water chemistry in the presence of bioturbating organisms.

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