# Microbial life at the air-sea interface

**Summary of the discussion session at the SOLAS Open Science Conference in Kiel, September 2015**

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The air-sea interface links the ocean and the atmosphere and, thus, controls a wide range of Earth system processes which are of profound interest for the SOLAS community and part of the SOLAS research strategies, e.g. sea spray aerosol formation and air-sea gas exchange (Law et al., 2013; http://dx.doi.org/10.1071/EN12159). The sea surface microlayer (SML) is located at the air-sea interface and is characterised by distinct physical, chemical and biological features compared to the underlying bulk water (recently reviewed by Cunliffe et al., 2013; http://dx.doi.org/10.1016/j.pocean.2012.08.004). Although microorganisms are known to be an integral part of the SML, a deeper understanding of the functional role of microorganisms in regulating processes at and across the air-sea interface is needed. The session "Microbial life at the air-sea interface" aimed (1) to discuss the potential role of microorganisms in regulating air-sea exchange processes directly at the interface and (2) to identify the most important gaps of knowledge from a multi-disciplinary perspective.
A brief introduction summarized the current knowledge about microbial structure and function in the SML and its potential influence on gas exchange and aerosol formation. The main topics addressed in the introduction were:

- the SML is a challenging habitat for microorganisms (e.g. due to accumulation of pollutants and strong exposure to solar radiation)
- the imbalance between auto- and heterotrophy close to the sea surface drives $CO_2$ / $O_2$ gradients
- there are indications for a microbial $CH_4$ sink in the SML
- organic material (OM) is generally enriched in the SML, but the microbial turnover of specific substrates is differently affected in the SML and the bulk water
- specific bacterial taxa are involved in OM turnover in the SML

This was the starting point for a very lively and interactive discussion among approximately 80 participants, which covered a broad range of specific interest in studying interfacial processes (Fig. 1). The main issues addressed were the following:

1) Problems associated to SML sampling:
   Due to the long time needed to sample sufficient amounts of the SML, the analysis of volatile gases might be biased by gas evasion/invasion during sampling. It was stated that some older literature shows that these effects might be negligable. Moreover, large volume samplers exist which reduce sampling time. However, generally this challenge remains and needs to be resolved. Likewise, measurements of biological activity might be biased because incubations are usually performed in containers, bottles, etc. which do not represent the original surface / volume ratio of the SML.

2) Biological *versus* photochemical turnover:
   The relative importance of biological *versus* photochemical processes was questioned several times during the discussion. In air-sea gas exchange, photochemical reactions might be the dominant factor to determine the half-life of highly reactive gases (e.g. $SO_2$), whereas other

gases (e.g. $CO_2$) might by mainly influenced by biological turnover. Similarily, OM is transformed by biological and photochemical processes, and thereby likely influences gas exchange and aerosol composition, but the relative importance is not known. The temporal dimensions of the occuring processes (i.e. «photochemical turnover = fast» *versus* «biological turnover = slow»?!) might give a better explanation but needs to be studied.

3) Biological activity *versus* dormancy:
The SML is characterised by rather harsh living conditions and there was discussion on whether this would favour niche formation for specific organisms. One potential adaptation mechanism could be pigmentation as a protective mechanism, although literature provides contradictory evidence if microorganisms in the SML benefit from pigmentation. Due to the large diversity of microorganisms in the SML, most likely the whole range from very actively metabolising to dormant or even dead cells exists. However, the underlying regulating factors are unresolved as is the temporal and spatial variability.

4) Night time studies:
Although some night/day cycle studies have been published, investigations of the SML during the dark are clearly underrepresented in the literature. Given that specific night time characteristica exist, e.g. migration of certain larger plankton, absence of autotrophic production and photochemical reactions, difference in temperature and heat exchange, night time studies could help to answer several of the open questions stated.

5) Trace metal deposition:
The discussion defined large gaps in the knowledge on how microorganisms in the SML might contribute to trace metal dissolution or insolubalisation by altering ligand availability or pH.

6) Organic material in sea spray:
There are large uncertainties about the composition of organic material (OM) in sea spray aerosols, which also reflects the unknown control of microbial processes to determine OM content in the SML. There is a need to differentiate OM production and transformation in the SML and to elucidate if / how these processes also occur within aerosols.

7) Stability of the SML:
Another aspect discussed was SML stability. Whereas most studies published so far have investigated the SML under low-wind conditions, it is unknown how organisms in the SML react to plunging by breaking waves at higher wind speed. Most likely the size of organisms plays an important role on how fast they are transported back to the SML and if they are negatively affected at all; but this remains to be studied. Additionally, bubble entrainment in the water column creates yet another "air-sea interface"; which, however, is challenging to investigate, e.g. due to different bubble size distributions. It was argued that standardised laboratory experiments could help to increase our understanding of physicochemical and biological interaction during SML formation, succession, and disruption (e.g. by bubbles).

8) Global feedbacks:
Large gaps of knowledge exist if SML properties are specifically affected by a changing climate (e.g. increasing wind speed) and if this, in turn, will specifically impact global feedbacks between the ocean and the atmosphere. Moreover, there is an urgent need to resolve anthropogenic forcing on SML structure and function, e.g. by accumulation of pollutants.

Overall, this discussion session identified the need for complementary measurements and campaigns. Therefore, the most important outcome of the session was the establishment of a group of persons interested in performing a joint experiment together. First preliminary ideas and plans were collected for this truly multi-disciplinary SOLAS approach in order to address several of the open questions and gaps identified during the discussion.

The conveners would like to thank all participants for this excellent discussion session and invite anyone interested in receiving more information about the session or the joint experiment to contact the conveners.

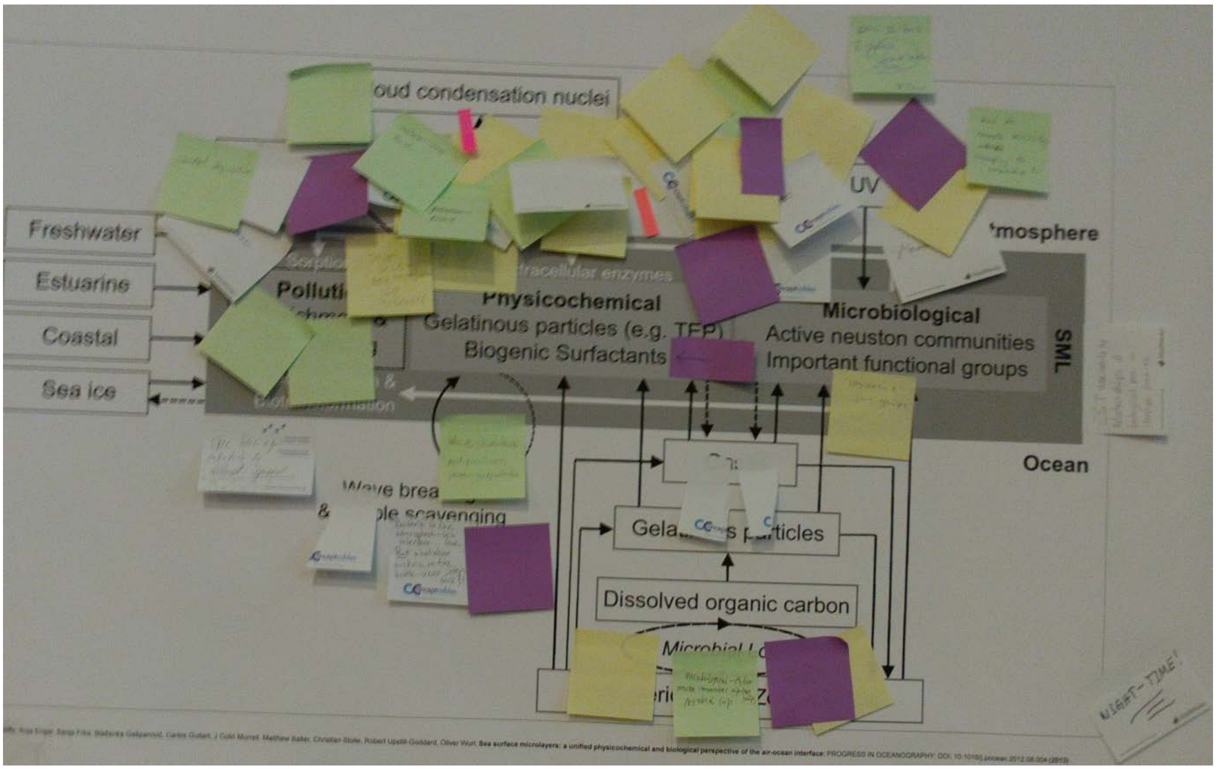


Figure 1: The participants of the discussion session “Microbial life at the air-sea interface” have identified their main interests as well as the most important gaps of knowledge about processes at the air-sea interface.