LEIBNIZ INSTITUTE FOR BALTIC SEA RESEARCH WARNEMÜNDE

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Upwards with the "bubble shuttle": How sea floor microbes get involved with methane reduction in the water column

For the first time, a research team from the Leibniz Institute for Baltic Sea Research Warnemünde (IOW) has been able to determine the efficiency with which methane-oxidising bacteria from the seafloor can travel with gas bubbles from submarine methane seeps into the open water column and influence biogeochemical processes there. This transport process can be of importance for the reduction of the greenhouse gas methane in the marine environment and thus for global climate developments.

Methane is one of the most potent greenhouse gases. How and where it reaches the atmosphere and which processes can prevent this, are therefore important climate-relevant questions, also in marine research. The focus here lies on various methane sources, mostly located at the sea floor, and on specialised microorganisms in the sediment and the water column that use methane as an energy source and thus remove it from the seawater.

These removal processes, which mainly involve methane-oxidising bacteria and methanotrophic archaeae, are so effective that usually almost no methane from the sea floor reaches the water surface and thus the atmosphere. However, the situation is quite different at submarine gas seeps, where methane is released from the sediment into the water column as gas bubbles. If the seeps are located in relatively shallow shelf areas, the microbial methane filter only works to a very limited extent because the bubbles rise to the sea surface so quickly that the methane rushes past the areas with methane-consuming microbes too quickly for them to get to work.

"Methane oxidising bacteria are conspicuously abundant in the water column above methane seeps," says Sebastian Jordan. "For a long time, it was unclear how these microorganisms can reach increased population densities there, because they only multiply very slowly and are constantly shifted by currents," the IOW researcher adds, who is working intensively on microbial processes associated with methane seeps in his doctoral thesis. "Since bubble-releasing gas seeps are important methane sources, we wanted to know more about how this phenomenon is caused and what influence these bacterial 'methane eaters' have on the methane flow from the sediment into the atmosphere," adds Oliver Schmale. The geologist has specialised in methane cycles in marine environments for many years and heads the DFG-funded Bubble Shuttle II project, which also includes the current study.

A pilot study at methane seeps off the Californian coast previously had explored the hypothesis that methane-oxidising sediment bacteria are swept up into the water column with rising methane bubbles. For this purpose, the scientists used the Bubble Catcher, a device specially developed at the IOW, which captures rising gas bubbles without contamination for the analysis of the bubble-attached bacteria. "We know since then that this 'methane bubble shuttle' upwards into the water column exists. However, many questions remained unanswered, for example whether the bacteria that are released into the open water column survive despite the drastic habitat change and how much influence the bubble transport actually has on the composition of the bacterial community in the water column," Schmale describes the approach for the new investigations.

Therefore, a team of IOW scientists, supported by US colleagues, carried out further bubble shuttle experiments in the Californian "Coal Oil Point" seep field at vents with different intensities of gas bubble release. They investigated the number of methanotrophic bacteria in the sediment, on the bubbles and in the water column, analysed their genetic composition and examined the influence of varying degrees of gas release intensity on the bubble transport process. In addition, on-site experiments were conducted to determine the methane reduction activity of the microorganisms adhering to the bubbles.

"That rising methane bubbles repeatedly inoculate the open water with methanotrophs from the sediment is supported by our genetic analyses. We have been able to detect the same methane-consuming microbes, for example from the family *Methylomonaceae*, as well as oil-degrading bacteria of the genus *Cycloclasticus*, in the sediment, on the bubbles, and in the water column," Sebastian Jordan describes one of the results. The efficiency of this transport is apparently determined by the intensity with which the gas comes out of the sea floor. Jordan: "If the gas slowly bubbles up, more than 20,000 methane oxidizers per millilitre gas can travel with it; if the gas flow is much stronger, it is only around 200." The experiments on methane reduction activity provided a clear indication that these passengers can survive and be active not only in the sediment but also in the open water. After three days, samples with trapped methane bubbles showed a methane oxidation rate 1000 times higher than those without.

"We also wanted to know whether bubble transport actually has sufficient potential to explain the increased population densities of methane oxidizers above seep fields. We used model calculations, which took into account factors such as transport distances, currents, different transport rates of bubble bacteria, etc., to successfully support this hypothesis," concludes Sebastian Jordan, first author of the recently published study.

"The study is the first to show in a conclusive 'all-round view' how microbial sediment dwellers influence bacterial communities in the water column by bubble transport and are involved in important biogeochemical processes such as methane reduction, which is relevant for the climate. This comparatively fast vertical transport process for microorganisms can also play an important role in other aquatic habitats and matter cycles, for example in lakes," concludes project leader Oliver Schmale.

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