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Petroleum biodegradation studied in sediment-flow-through systems simulating natural oil seepage in marine sediments

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The natural biodegradation of hydrocarbons depends on several environmental factors like nutrients, salinity, temperature, pressure, redox-conditions and composition of crude oil. Petroleum migrating from depth into marine surface sediments at natural seep sites could be subjected to a sequence of different kind of microbial processes which is controlled by a strong redox gradient within a thin sediment segment. Most studies on microbial degradation of petroleum have focused either only on selected hydrocarbon fractions or on cultured microbes. This study, however, attempts to investigate the natural microbial response of marine sediments to crude oil seepage with detailed analysis of sediment and porewater geochemistry, hydrocarbon degradation products, microbial activity, and microbial genetics.

A sediment-oil-flow-through-system was established where crude oil migrated through the bottom of (approximately 30 cm long) intact marine sediment cores simulating a natural seepage scenario. Electron acceptor-rich oxic seawater was provided at the top of the core and anoxic conditions were established at the bottom of the cores. The intact sediment cores had been sampled from the Caspian Sea (near Baku) and the North Alex Mud Volcano in the Mediterranean Sea. The Caspian Sea and the North Alex Mud Volcano are both sites with active transport of hydrocarbons from depth by mud volcano activity. The geochemical changes in the sediment cores during oil seepage were monitored by using microelectrodes and porewater analyses. The geochemical analysis was later followed by hydrocarbon and molecular analyses at the end of the experiment by slicing the cores.

First results based on the biogeochemistry of the sediment cores and hydrocarbon analyses are presented here. Porewater profiles of hydrogen sulfide and sulfate during the experimental runs gave first indications of microbial response and sulfate reduction due to the addition of crude oil. The core from North Alex Mud Volcano showed a faster response to crude oil and established an active sulfate reduction zone. A slower response of sulfate reduction was observed in the Caspian Sea core, possibly controlled by either fixation of produced sulfide by high sedimentary iron content or the presence of a microbial community that is less adapted to petroleum. Moreover, C1-C6 hydrocarbon analyses probably indicate a methanogenic zone established in the Caspian Sea core. Further differences and similarities between the two mud volcano-related sediments will be discussed in the light of their natural potential for petroleum degradation.