OIL PLUME DEGRADATION BY UNDISTURBED DEEP SEA MICROBIAL COMMUNITIES, USING A NOVEL HIGH-PRESSURE APPARATUS

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ABSTRACT

Background information/Objectives

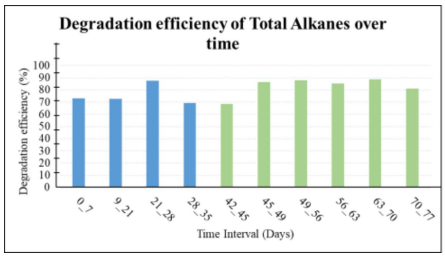
In the recent years, the exploration and exploitation of more and more inaccessible offshore deposits of hydrocarbons, has caused an increased concern for another deep-sea oil spill accident. Deep-sea bioremediation came to the fore after the Deepwater Horizon accident in the Gulf of Mexico in 2010. Subsea dispersant application and the live oil released at 1,500 m depth, resulted in the formation of small neutrally buoyant oil droplets, which remained underwater and formed subsurface plumes at depth, the largest and deepest of which was found between 1,000-1,200 m depth ("deep plume"). Dispersant application under high-pressure conditions to this day remains controversial and is still unclear whether it actually enhances oil bioremediation. Approximately 41% of hydrocarbons discharged during the DWH accident were entrapped subsurface and degraded by the autochthonous microbes, including the majority of the deep plume hydrocarbons. To this day there is little documentation regarding biodegradation rates to accompany the observed decrease in hydrocarbon concentrations related to microbial response. Most studies of oil biodegradation in the deep-sea are conducted under atmospheric pressure or by re-pressurizing the samples in the lab, thus providing non representative biodegradation rates.

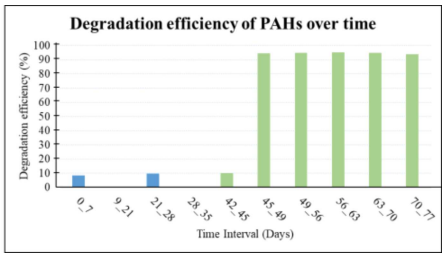
Methodology

For the collection of deep-sea water samples, a simple and practical high-pressure sampling device (HP-Sampler) was designed to maintain pressure upon retrieval. The HP-Sampler is equipped with a unidirectional check valve and set to retrieve seawater at a specific depth range by opening and closing at a pressure difference of ~2 bar. A known volume of sample from the HP-sampler is then passed into a high-pressure reactor (HP-Reactor) for experimentation via a high-pressure syringe pump (HP-Pump) without pressure disruption. This set-up was used to study the degradation of crude oil hydrocarbons at plume concentrations by deep-sea microbial communities collected from the Eastern Mediterranean Sea (EMS) with and without dispersant application. The renewed interest of the area's hydrocarbon deposits along with the fact that Mediterranean Sea is a semi-enclosed sea in which multiple countries owe their prosperity, showcase that a deep-sea hydrocarbon release would be destructive for the countries that surround it. Un-decompressed seawater was retrieved from a depth range between 600 – 1,000 m and successfully incubated for 77 days in the HP-Reactor at 100 bar and *in situ* temperature (14°C). In the first part of the experiment, light Iranian crude oil was added at day 0 to a final concentration of approximately 1 ppm and was replenished regularly until day 35. The incubation was maintained for a week prior to the second part of the experiment (42-77 days), which involved the addition of dispersed crude oil (1:25 v/v COREXIT 9500) at approximately 10 ppm concentration with weekly replenishment. Alkane and polycyclic aromatic hydrocarbons concentration was determined at predefined time points via GC-MS analysis. Based on the GC-MS results, kinetic analysis was conducted to obtain biodegradation rates.

Main results

Microbial response was rapid after the addition of oil. In the first 3 days, population grew rapidly and achieved more than 70% degradation of the total petroleum hydrocarbons measured. By the end of the first treatment, the community has been well adapted to oil biodegradation and even after a week of incubation prior to the second treatment, the microbes achieved a very high degradation efficiency of the dispersed oil; more than 80%. Background nutrient levels seemed to be adequate for the microbial metabolism of the crude oil. First order kinetic evaluation between the first three days of each treatment and the last 7 days, showed that the alkanes were highly degraded regardless of dispersant application. Dispersant seemed to enhance the degradation of the heavier alkanes (C_{26}-C_{35}) and polycyclic aromatic hydrocarbons; more than 90% degradation efficiency of PAHs was achieved with the dispersion of oil.





Conclusions

To the best of our best knowledge, this is the first complete emulation study of a deep-sea hydrocarbon plume using indigenous microbial populations without any pressure disruption. Examining the behavior of indigenous EMS microbial communities under *in situ* conditions, proves that deep-sea EMS communities are competent enough to combat deep-sea oil spills with no additional input of nutrients. Biodegradation rates of the lighter alkanes are in accordance to other published data regarding plume concentrations of crude oil, but there is a distinct difference for the more recalcitrant compounds such as the heavier alkanes and PAHs, where rates are significantly lower, indicating that high pressure is essential for the study of deep-sea microbial communities. The importance of high pressure is also highlighted by the immediate action of the microorganisms without any observed lag phase which is the case for most studies. Dispersants seem to have a positive effect on biodegradation rates of HA and PAH, however other parameters must be taken into consideration prior to the application of dispersants in a deep-sea environment.

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