

Crude oil emulsifying bacteria

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-possibilities and limitation



Lessons from a 6 year project 1988-1994 financed by FINA Exploration Norway u.a.s.

Crude oil emulsifying bacteria are able to transform crude oil into an oil-in-water emulsion. By adding suitable bacterial strains to oil spills we can disperse the oil as small oil droplets that will be mixed into the water masses and further degraded by indigenous bacteria in the environment. In particular such bacteria may be used to remove crude oil from polluted shorelines.

What are crude oil emulsifying microorganisms?

A large number of bacteria, yeast and fungi are able to metabolize one or more compounds in crude oil. A few species of microorganisms, in particular bacteria, are able, by de novo synthesis, to produce surface active compounds, so called biosurfactants. Crude oil emulsifying microorganisms are able to transform crude oil into an oil-in-water emulsion, often by a combination of production of biosurfactants and generation of surface active degradation products through their metabolism of crude oil components. Oil-in-water emulsions made by good crude oil emulsifying bacteria can be very stable and stored for years without significant coalescence. Furthermore, crude oil emulsifying microorganisms are able to transform also very weathered crude oil into an oil-in-water emulsion.



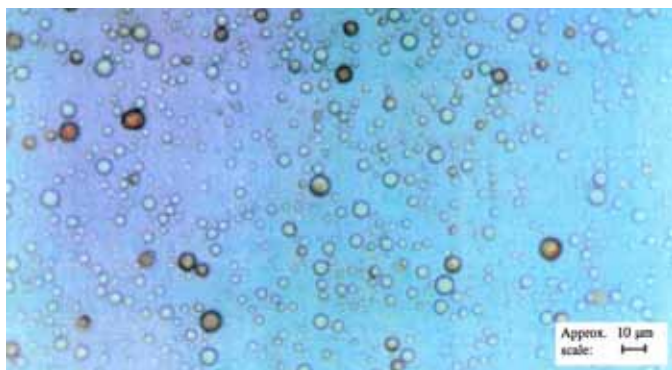
A shake flask with bioemulsified crude oil

Why add crude oil emulsifying bacteria to oil spills?

Crude oil emulsifying bacteria are naturally present in the marine environment. However, crude oil is not usually transformed into an oil-in-water emulsion to any significant degree after oil spills. Thus, in nature crude oil emulsifying bacteria usually lose out to other crude oil degrading microorganisms in the competition for limited resources (N, P, Fe, etc). Through their activity crude oil emulsifying bacteria probably can enhance the overall natural degradation of crude oil in the marine environment. However, because they are unable to compete successfully with other crude oil degrading bacteria, they do not normally become a dominant factor after oil spills, and their potential for enhancing oil degradation is not fulfilled. By adding suitable, good crude oil emulsifying bacteria we can make these bacteria dominating at least for a short period, and the oil will be transformed into an oil-in-water emulsion and dispersed in the sea. The large surface to volume ratio, together with the dispersion, which leads to a better balance between carbon source (oil) and other nutrients, will enhance the biodegradation of the oil. A degradation that will be performed by local, well adapted crude oil degrading microorganisms.

Emulsification of weathered crude oil in a flume basin

An experiment was performed in a flume basin (approx. 2000 L) designed to reflect open sea conditions with respect to wind, waves, and temperature. Statfjord crude oil (1 %) was added to the seawater in the flume basin and allowed to weather for two days at 14-15 °C, wind velocity corresponding to a light breeze, and moderate wave action. After two days a typical "chocolate mousse" had been formed. Then two selected strains of crude oil emulsifying bacteria were added together with N- and P-nutrients. Within 15 hours the chocolate mousse had been mixed into the water as an unstable emulsion with relatively large oil droplets. During the following days the average oil droplet size steadily decreased, and the emulsion became correspondingly more stable. After 48 hours the average droplet diameter was 19 µm and a stable oil-in-water emulsion had been formed.



Bioemulsified crude oil droplets. The bacteria are stained and have a red to brown colour. Oil droplets with a high number of bacteria attached therefore have a brown colour, while droplets without bacteria appear clear.



In less than one day the chocolate mousse in the flume basin was dispersed in the water as an unstable oil-in-water emulsion. Over the next days the average oil droplets size became smaller and smaller, and the emulsion more and more stable.

Removal of oil from beaches

The need to emulsify or disperse the oil in the open ocean rapidly, often within hours, may make bacterial emulsification a too slow process in many cases. However, for oil polluted shorelines the treatment time is currently in the order of days to weeks, and sometimes even years, and in this time frame bioemulsification is no longer a slow process. In laboratory experiments in shake flasks it was shown that crude oil adhering to pebbles and sand particles could be washed off and transformed into an oil-in-water emulsion. However, experiments showed that in order to remove and emulsify stranded crude oil on beaches it is important that the strain is suited to the shore environment, in particular temperature, pH and salinity. By adding in the order of 1-10 g dry weight emulsifying bacteria per square meter to an oil polluted shoreline we ensure that they constitute a significant fraction of the total microbial population for a period, and we have shown that a fairly large fraction survives for at least a few weeks in simulated shore environments. However, in order to perform their intended job (emulsification of the oil) they must also be able to function satisfactory under the in situ environmental conditions. Thus, tropical and arctic shores will require different strains.

Other experiences and experimental methods developed in the project

Crude oil emulsifying bacteria constitute only a small fraction of the total microbial flora in natural environments, and good crude oil emulsifying bacteria are even much rarer. However, in the project we developed efficient enrichment and screening methods to isolate good crude oil emulsifying bacteria. Furthermore, methods to cultivate the selected strains in large quantities and preserve them in a viable state by drying were also developed.



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