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STUDY TITLE: Degradation of Synthetic-Based Drilling Mud Base Fluids by Gulf of Mexico Sediments

REPORT TITLE: Degradation of Synthetic-Based Drilling Mud Base Fluids by Gulf of Mexico Sediments, Final Report

CONTRACT NUMBER: 1435-01-01-CA-31179

SPONSORING OCS REGION: Gulf of Mexico

APPLICABLE PLANNING AREAS: Eastern Central and Western Gulf of Mexico

FISCAL YEARS OF PROJECT FUNDING: 2001-2005

COMPLETION DATE OF REPORT: August 2006

COSTS: FY 2001: $148,664; FY 2002 $105,810: FY 2003: $64,924, FY 2005: 56,430 (projected)

CUMULATIVE PROJECT COST: $391,847

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KEY WORDS: synthetic base fluids, biodegradation, kinetics, fate model

BACKGROUND: An important consideration in the environmental assessment of deep-sea drilling operations in the Gulf of Mexico is the discharge of cuttings coated with synthetic-based fluids (SBF). Synthetic-based fluids are one type of nonaqueous drilling fluid and are used in drilling mud to lubricate the drill bit, control reservoir pressure, and bring rock chips, or cuttings, to the surface. Synthetic-based fluids, which can be composed of linear alpha olefins, internal olefins, esters or paraffins, are released into the marine environment as a residue on the cuttings as they are discharged. This study addresses the fate of the synthetic base fluid portion of the drilling mud in Gulf of Mexico sediments by determining the potential of marine sediment microbes to degrade representative SBF under deep-sea conditions. This study will also examine the effect of the discharge on the microbial ecology of the sediments. The Environmental Protection Agency (EPA) has chosen the anaerobic Closed Bottle Testing (CBT) as the method of choice for determining the biodegradability of synthetic drilling mud base fluids. This test was chosen over other tests because it is more environmentally relevant. However, the CBT currently relies on the use of a limited number of near-shore sediment samples as representative inocula.

The use of more representative sediments, specifically deep-sea sediments obtained from "pristine" and impacted areas of the Gulf of Mexico will help to improve the understanding of how microbial populations react to the addition of SBF. A model to predict how fast the sediment will recover under realistic conditions will form a scientific basis for evaluating impacts from the discharge of SBF in the deep-sea.

OBJECTIVES: The objectives of this study are to 1) establish the relationship between chemical structure and the rate of removal of synthetic base fluids from deep-sea sediments incubated under relevant temperature and pressure conditions; 2) characterize microbial populations involved in the removal of SBF and determine the response of the microbial community; and 3) develop a model which incorporates microbial response, environmental conditions, and base fluid structure to estimate the response and recovery of impacted deep-sea sediments.

DESCRIPTION: Sediments collected from three locations in the Gulf of Mexico, 66 m to 1135 m depth, near field and far field locations were used in a modified CBT method to measure degradation rates of surrogate SBF tetradecene and ethyl oleate. The sediments were incubated at 4°C and under a hydrostatic pressure equal to that of the depth they were taken from, or at atmospheric pressure. The microbial population in the sediments was characterized by fluorescent in-situ hybridization (FISH) and most-probable number (MPN). A model that can be used to predict the fate of SBF deposited to the floor of the Gulf of Mexico was developed.

SIGNIFICANT CONCLUSIONS: The significant conclusions of the study are that there are cold tolerant, anaerobic microorganisms that can degrade the surrogate SBF components tetradecene and ethyl oleate in sediments from the Gulf of Mexico. Sulfate was determined to be the major electron acceptor involved in the degradation process. Analyses of the microbial ecology of the sediment were not as useful as had been hoped due to interference of natural sediment components with the methods used for analyses. The results did show an increase in the number of sulfate reducing bacteria (SRB) present in sediments that had been exposed to SBF (comparing impacted samples with unimpacted) or incubated in the presence of surrogate SBF tetradecene or ethyl oleate. The study also showed that the EPA CBT could be adapted to reflect deep sea pressure. The anaerobic incubations revealed that the removal of ethyl oleate from a contaminated site could be described using a first order k value of -0.22 ± 0.02 $week^{-1}$. The removal of ethyl oleate from an uncontaminated site would occur at a rate of -0.11 ± 0.02 $week^{-1}$. A lag time for ethyl oleate removal is predicted to be between 0 and 11 weeks. The average first order decay coefficient (k value) for the removal of tetradecene linked to sulfate reduction was -0.05 ± 0.01 $week^{-1}$. Tetradecene degradation typically required a much longer lag period, (4-28 weeks).

STUDY RESULTS: Sediment samples were collected from the Gulf of Mexico. The sediments were spiked with surrogate SBF (tetradecene and ethyl oleate) and incubated under anaerobic conditions. An incubator which reproduces the pressure at more than 1000 meter water depth was constructed for testing SBF biodegradation in sediments from the deepest sampling location. Bacteria in the sediments have the capability to degrade SBF. A mathematical model to predict SBF biodegradation has

been constructed. This study received a 12-month extension and additional funding to extend the sediment incubation period.

STUDY PRODUCTS: The written products of this study include three masters theses, a Ph. D. dissertation, numerous quarterly status reports, a final report, and at least two peer reviewed publications (planned for submission). The results of the research have been presented in the MMS ITM conferences in 2002, 2003 and 2005, at the International Petroleum Environmental Conference (IPEC) in 2003, the American Society for Microbiology Annual meeting in 2003 and 2005, and the Applied and Environmental Microbiology Gordon Research Conference in 2005.

Roberts, D.J. and A.H. Nguyen. 2006. Degradation of synthetic-based drilling mud base fluids by Gulf of Mexico sediments: final report. U.S. Dept. of the Interior, Minerals Management Service. Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2006-028. 140 pp.

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Map Showing area of study