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Project Summary

Fate and Biological Effects of Oil Well Drilling Fluids in the Marine Environment: A Literature Review

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The document described by this project summary reviews research data published in the scientific literature regarding the potential impact of drilling fluids on the marine environment. Researchers have found that predictions of impacts are difficult because no two drilling fluids are identical. The mixtures are custom formulated to perform a variety of functions integral to each drilling operation. Further, drilling fluids are released in a variety of marine systems from arctic to temperate seas. Published research data indicate that lethal and sublethal concentrations of drilling fluids on various marine organisms vary from about 100 parts per million (ppm) in coral to more than 1000 ppm in other less sensitive organisms. Recommendations are summarized for the prevention or amelioration of damage from drilling fluids to the marine environment. Further research is suggested to close gaps in current knowledge about behavior of drilling fluids in aquatic ecosystems.

This Project Summary was developed by EPA's Environmental Research Laboratory, Gulf Breeze, FL, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Drilling fluids or muds have a variety of functions integral to rotary drilling for oil and gas. Drilling fluids are custom formulated to perform these functions optimally under the unique conditions of each drilling operation. Therefore, no two drilling fluids are identical. Although there are more than 1,000 trade-name products and generic materials available for formulating drilling fluids, 90 percent or more of the total ingredients of most water-based muds used offshore in U.S. waters consists of four materials, barite, bentonite clay, lignite and lignosulfate. The total number of ingredients in a majority of drilling fluids ranges from 8 to 12.

During normal exploratory drilling operations, water-based drilling mud may be discharged in small quantities with cuttings on a nearly continuous basis. Larger bulk discharges of mud may occur several times during the two to six months usually required to drill a well and a few times at the end of the drilling. The total volume of mud discharged during the drilling of a well is quite variable, but usually falls in the range of 100 to 400 metric tons.

When discharged, the drilling mud forms a plume which drifts away from the rig with the prevailing current. Fractionation of the drilling mud occurs rapidly as dense particulates settle to the bottom and fine clay-size particulates and soluble materials are carried downcurrent. Substantial dilution may take place in the discharge pipe before the mud is discharged. Drilling mud concentration, measured as total suspended solids, percent transmittance, or concentration of particulate or soluble mud-associated metals, decreases rapidly with distance from the rig. Background values for total suspended solids and soluble/particulate metals concentrations are usually reached within 100 to 1,000 meters (m) downcurrent of the discharge. Using ultratrace techniques for particulate barium, it is possible to trace a drilling mud plume for several km. Percent transmittance values, indicative of fine suspended clay-size particulates, usually reach background somewhat further downcurrent than suspended solids concentrations. The time required for the drilling mud plume to be diluted and dispersed to background levels is 30 to 100 minutes.

Rate of dilution to background of discharged drilling mud is affected by the rate of drilling mud discharge, current speed and turbulence, water depth and other hydrographic parameters. Dilution rate can be controlled somewhat by controlling rate of mud discharge and discharge pipe design and position in the water column.

Virtually all of the drilling mud solids and some of the soluble components eventually are deposited on the bottom under and downcurrent from the discharge pipe. Maximum drilling mud accumulation on the bottom usually occurs a short distance downcurrent from the discharge. The most useful tracer of distribution of drilling mud in bottom sediments is barium. Surficial sediments (upper 1 cm) up to about 2 km downcurrent from the mud discharge may contain elevated concentrations of barium. Elevated concentrations of chromium, lead, and zinc may occur in bottom sediments near the discharge. Concentrations of these metals in sediments fall to background concentration at a much shorter distance from the discharge than does sediment barium concentration.

The major environmental concerns about discharge of used drilling muds to the ocean are that they may be acutely toxic or cause deleterious sublethal effects in sensitive organisms and ecosystems and that heavy metals associated with drilling muds may be accumulated by marine organisms to dangerous concentrations.

A majority of major drilling mud ingredients are biologically inert or have a very low order of acute toxicity. Of the major drilling mud ingredients, only chrome- and ferrochrome-lignsulfonates can be considered at all toxic. Their toxicity is quite low to all but a few sensitive species (e.g., some corals). Minor ingredients of some environmental concern include sodium phosphate salts, detergents, biocides (chlorinated phenols no longer are permitted for offshore disposal), chromate salts and asphalt/oil-based ingredients. Ordinarily, these materials are not used in large enough quantities to cause concern. Their concentrations should be kept low in drilling muds destined for ocean disposal. Where possible, less toxic substitutes should be used.

Results and Conclusions

To date, the acute toxicity and sublethal biological effects of more than 20 drilling muds used offshore have been evaluated with more than 60 species of marine animals from the Atlantic, Pacific, Gulf of Mexico and Beaufort Sea. Representatives of five major animal phyla were tested, including Chordata, Anthropoda, Mollusca, Annelida, and Echinodermata. Larvae and other early life stages, and oceanic species (considered to be more sensitive than adults and estuarine species to pollutant stress) were included. In all but a few cases, acute toxicity, usually measured as 96-hr. LC_{50}, was 10,000 ppm or higher drilling mud added. The lowest acute LC_{50} value was 500 ppm for stage I larvae of dock shrimp *Pandalus danae* exposed to a high density ferrochrome-lignosulfonate drilling mud from Cook Inlet, Alaska. Chronic or sublethal responses were observed in a few cases at concentrations as low as 50 ppm.

Field studies of drilling mud plume dilution and dispersion revealed that drilling mud concentrations high enough to cause acute or sublethal damage to the most sensitive species and life stages should occur only in the immediate vicinity of the drilling mud discharge (to less than 1,000 m downcurrent) and only for a very brief time during bulk discharges (generally less than 2 hours). Therefore, we can conclude that adverse impacts on water column organisms of discharge of used water-based drilling muds to the ocean should be moderate and of short duration.

Benthic fauna may be vulnerable to damage from settling drilling mud and cuttings solids, through burial or chemical toxicity. Accumulation of drilling muds in coarse bottom sediments may change sediment texture and thereby affect recruitment to the benthos of planktonic larvae. At environmentally realistic levels of drilling mud in sediment, species composition of the benthic community changes toward a more silt/clay-tolerant assemblage. The species most sensitive to drilling mud in the water or sediments appear to be very sensitive high suspended particulates concentrations. Limited field studies indicate that recovery of the benthic community from any effects of discharged drilling mud is likely to be very rapid (within a few months).

Heavy metals associated with drilling muds have a very limited bioavailability to marine animals. Chromium is the most bioavailable of the mud-associated metals. Accumulation from drilling mud of small amounts of barium, lead, cadmium and copper was demonstrated a few times when marine animals were exposed to high concentrations of drilling muds or drilling mud ingredients. Field studies in the vicinity of drilling mud discharges have not provided any convincing evidence of metal accumulation by resident marine fauna. More research is needed on the long-term bioavailability to benthic marine organisms of metals from sediments comtaminated with realistic amounts of used drilling muds.

Discharge of used water-based drilling fluids to the ocean or exposed coastal waters, where rapid dispersion and dilution are possible, poses no as yet measurable hazard of more than very localized and transitory impact on the marine environment. Even in the small temporal and spatial domain in which an adverse impact can be observed or predicted, damage is likely to be of a low order of magnitude and restricted primarily to the benthos. Metals associated with used drilling fluids have a very limited bioavailability to marine organisms, so there is little danger of food-web transfer or biomagnification of mud-associated metals to commercial fishery species or Man. These conclusions apply to standard or typical water-based drilling fluids currently in use for exploratory drilling in U.S. coastal waters and outer continental shelf. Higher modified or specialized mud formulations or completely new formulations or ingredients that might be introduced may behave quite differently in the marine environment than the majority of drilling muds evaluated to date.

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The complete report, entitled "Fate and Biological Effects of Oil Well Drilling Fluids in the Marine Environment: A Literature Review," (Order No. PB 82-240 391; Cost: $16.50, subject to change) will be available only from:
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