Synthetic-Based Drilling Mud Spills

Definition

Drilling muds are used to lubricate and cool the drill bit, control reservoir pressure, and transport drill cuttings back to the surface during oil exploration and development. There are three types of drilling muds: oil-based, water-based, and synthetic-based.

In contrast to synthetic-based fluids, both oil-based (i.e., diesel oil and/or mineral oil, containing polycyclic aromatic hydrocarbons [PAHs]) and water-based drilling fluids are considered to be traditional materials, which have lower drilling performance and are associated with greater water and sediment quality issues.

Synthetic-based drilling muds (SBMs) are often used during drilling of deep water and directional wells. EPA prohibits the discharge of synthetic-based drilling muds and oil-based drilling muds and cuttings. Bulk drilling muds are not intentionally discharged; however, drilling fluids that include drilling mud and cuttings may be treated to remove the bulk of the drilling mud (cuttings can contain ~10% synthetic chemical content) and discharged in Federal waters in the Gulf of Mexico and Cook Inlet, AK. Both synthetic-based drilling muds and cuttings mixed with the muds can be accidentally discharged, and these products are addressed in this fact sheet.

Properties

- SBMs are generally comprised of 30-90% by volume (20-50% by weight) of synthetic organic compounds (which act as lubricants), that are dispersed in a salt brine to form an emulsion, along with other ingredients including emulsifiers, wetting agents, a weighting material (usually barite, $BaSO_4$, or ilmenite, $FeTiO_3$), clays, lignite, and lime. They are much denser than sea water.
- The brine is dispersed into the organic phase to form a water-in-organic emulsion which is very stable, as emulsifiers are used to keep water droplets down to less than 1 micron in diameter. The organic/water volume ratio is varied to alter mud viscosity and usually ranges from 55/45 to as high as 96/4.
- The most common synthetic organic compounds in SBMs are olefins (monounsaturated acyclic hydrocarbons that contain an even number ($_n$) of carbons between 8 and 20: C_nH_{2n}), although esters and linear alkyl benzenes are also used.
- Olefins are not present in most crude oils and refined products, so they can be used to fingerprint the presence of SBMs in sediments.
- SBMs are synthesized specifically to not include PAHs, thus having lower environmental impact and lower toxicity for workers.

Environmental Behavior

- SBMs enter the marine environment as a coating on drill cuttings when discharged from the drilling platform, and as accidental spills.
- Drill cuttings are “oil-wet” and, when discharged to the ocean, tend to clump together in large particles that settle rapidly to the seafloor, forming piles usually within 800 feet of the platform.
- However, drill cuttings containing less than about 5% SBM do not clump when discharged to the ocean; they disperse and settle over a wide area, preventing development of a cuttings pile and speeding biodegradation.
- Concentrations of the water-soluble components are unlikely to exceed about 1 mg/L at any time during routine discharges of drill cuttings.

- The only study of a release of bulk SBMs was after the April 2010 Deepwater Horizon event, where large volumes of SBMs were quickly released at the seafloor during the blowout and top kill operations (Stout and Payne, 2018). Samples collected from September 2010 to October 2011 showed that the SBM-contaminated sediments extended 3300 to 7000 feet around the well. The larger footprint around the well was likely due to the absence of heavy, "oil-wet" drill cuttings in the released fluids. Months after the blowout, olefins in sediments in the top 1 cm of the seafloor were as high as 28,654 micrograms per gram (µg/g), and averaged 3270 µg/g, with concentrations decreasing by orders of magnitude with sediment depth (1-5 cm). By 2014, olefins in the top 1 cm decreased to an average of 372 µg/g, whereas there was little change in concentrations with depth. The olefins showed evidence of biodegradation, but to highly varying degrees.
- The organic compounds in SBM are readily biodegraded under aerobic conditions. Monitoring around drilling platforms has shown that olefins in sediments decreased within 1-2 years after discharge as a result of resuspension, bioturbation, and biodegradation. However, if the initial SBM concentration is high enough, the sediments become anoxic and biodegradation slows. Stout and Payne (2018) reported weathered olefins in sediments (range of 7-1219 µg/g, and average of 247 µg/g) at a drilling site 13 years after drilling ceased, indicating long-term persistence in deep-sea sediments.

Environmental Effects

- SBMs and their biodegradation products exhibit low toxicity to water-column organisms, and thus there is low risk of direct toxicity from the settling material. Because SBM cuttings clump and settle rapidly, impacts associated with increased water-column turbidity are likely of short duration. However, slow moving and sessile benthic fauna within the footprint of the deposition zone are at risk of smothering by the settling material.
- The metals in SBM discharges have a low bioavailability and low toxicity to marine organisms, because they are in solid or complexed forms and will either disperse or settle out to the seafloor. They are associated with dispersed cuttings and solid additives (barite and clays), not with the continuous phase (water, oil, or synthetic), in drilling fluids.
- Filter feeders such as mussels have shown rapid uptake of SBM chemicals in laboratory tests (and rapid elimination when placed in clean water). Damage to gills of suspension- and deposit-feeding bivalves has been reported in laboratory tests with barite, a major constituent of SBMs.
- In areas of high SBM concentrations in sediments, the sediments can become oxygen depleted due to the increased biological oxygen demand of aerobic biodegradation. When this happens, sensitive species can die off and be replaced by hardier opportunistic species. This decrease in benthic biological diversity can be reversed when anaerobic biodegradation of the drilling mud organics lowers their concentration enough for the sediments to become re-oxygenated, although it may take years for recovery to be complete (Neff et al., 2000).

Key References

Neff, J.M., S. McKelvie, and R.C. Ayers Jr. 2000. Environmental impact of synthetic based drilling fluids. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Study MMS 2000-064. 118 pp. Available at: http://www.data.boem.gov/PI/PDFImages/ESPIS/3/3175.pdf.

Stout, S.A. and J.R Payne. 2018. Footprint, weathering, and persistence of synthetic-based drilling mud olefins in deep-sea sediments following the *Deepwater Horizon* disaster. Marine Pollution Bulletin 118:328-340.