

## The Base Fluid Dilemma: What Can We Use and Where Can We Use It?

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This paper was prepared for presentation at the 2008 AADE Fluids Conference and Exhibition held at the Wyndam Greenspoint Hotel, Houston, Texas, April 8-9, 2008. This conference was sponsored by the Houston Chapter of the American Association of Drilling Engineers. The information presented in this paper does not reflect any position, claim or endorsement made or implied by the American Association of Drilling Engineers, their officers or members. Questions concerning the content of this paper should be directed to the individuals listed as authors of this work.

### Abstract

A little over five years ago, the fate of the future use of synthetic base fluids in the Gulf of Mexico was determined by the EPA in their Effluent Limitation Guidelines. A little over seven years ago, the fate and future of synthetic-based fluids in the North Sea was determined by OSPAR. Since then the activity and issues surrounding the use of synthetic base fluids and other NAF's have continued to evolve in other regulatory jurisdictions. These issues not only focus around the definition of synthetics and the environmental impact of the individual base fluids, but also health and safety concerns and test methods for assessing these attributes. This paper provides an overview of the global market for base fluids used in drilling fluids and the drivers in each of these regions.

### Introduction

Synthetic-based drilling fluids or "muds" (SBMs) were introduced into the North Sea market in the early 1990's with the intention of providing oil-based drilling fluid (OBM) performance while addressing the environmental issues with traditional oil-based drilling fluid formulations. The use of manufactured fluids build from purified chemical feedstock provides the physical properties of oil-based drilling fluids while addressing their chemical attributes that can cause environmental problems (e.g. toxicity, biodegradation, bio-accumulation, aromatic compounds). In the North Sea, SBMs that the met testing limits in place at the time were allowed to be discharged as more data on seafloor impacts was developed.

In the mid 1990's synthetic-based drilling fluids were introduced into the Gulf of Mexico (GOM) market. At the time, the US EPA allowed the discharge of SBM cuttings on the basis that they met WBM discharge limitations. Initially, the EPA recognized the pollution prevention opportunities for SBM technology<sup>1</sup> and allowed the discharge of SBM cuttings, but did not define any additional limitations while they collected information on SBM cuttings discharges.

When the regulatory process was completed in the North Sea, a decision was made to effectively eliminate discharges of SBM cuttings and require operators to either haul the cuttings to shore or inject them offshore. In the US, when the regulatory process was complete, a decision was made to allow controlled SBM discharges.

Since these regulatory decisions have been made in the North Sea and the US, the associated markets have adapted

and continue to evolve. Other regions have looked at both approaches to SBM technology and have generally selected controlled discharges. In each region, the selection of the synthetic base fluid (SBF) and solids-control technology within the context of regional environmental and regulatory concerns continues to have a major impact on drilling operations. In addition to base fluid selection offshore, the onshore selection has also evolved over time in some regions while remaining stagnant in others regions.

### Background

#### US Offshore

In December 2000 EPA published a Final Effluent Limitation Guideline for synthetic-based drilling fluids and other non aqueous fluids.<sup>2</sup> In December 2001, EPA published a final modification of general permit of the National Pollutant Discharge Elimination System (NPDES) for the Western Portion of the Outer Continental Shelf of the Gulf of Mexico (No. GMG290000)<sup>3</sup> with an effective date of February 2002 for the permit. Clear authorization for discharge of SBM cuttings was the major change in the permit from previous versions. Along with the specific permission to discharge SBM cuttings, the EPA included new requirements in the permit to control SBM discharges. Since that time in the Gulf of Mexico, synthetic-based muds have been the dominating fluids technology in challenging deepwater applications combined with controlled discharge of SBM cuttings.

The fundamental decision to allow controlled discharges of SBM cuttings was driven by recognition of non-water quality impacts and significant improvements in solids-control equipment that reduced organic loads from discharges of SBM cuttings. Some of the specific statements made by the EPA in the final ruling<sup>2</sup> included the following elements:

- "0" discharge would result in:
  - 35 million more pounds of cuttings shipped to shore for disposal
  - 166 million more pounds of cuttings injected
  - Increase fuel use 358,664 BOE
  - Increase in air pollution 5602 tons
  - 51 million pounds more WBF cuttings discharge
  - Landfilling of cuttings from OBM is of a longer term duration than those from SBF and associated pollutants may affect ambient air, soil, and groundwater quality. EPA and DOE

documented at least five CERCLA (or "Superfund") sites in Louisiana and California contaminated with oilfield wastes and more than a dozen other sites subject to Federal or State cleanup actions.

- Controlled discharges would result in:
  - Lowered organic loading.
  - Lowering the percentage of residual drilling fluid retained on cuttings would increase the recovery rate of the seabed receiving the cuttings
  - Limiting the amount of SBF content in discharged cuttings controls: (1) The amount of toxic and non-conventional pollutants in SBF which are discharged to the ocean; (2) the biodegradation rate of discharged SBF; and (3) the potential for SBF cuttings to develop cuttings piles and mats which are deleterious to the benthic environment.

The long-term average (LTA) performance of the baseline solids-control technology is 10.2%, as compared to the LTA of 4.8% based on data from all four cutting dryer technologies. This difference translates to 118 million pounds per year of pollutants being discharged using the existing and new model well counts for the selected Best Available Technology (BAT) option.

Field results show that: (1) Cuttings are dispersed during transit to the seabed and no cuttings piles are formed when SBF concentrations on cuttings are held below 5%; and (2) cuttings discharged from cuttings dryers (with SBF retention values under 5%) in combination with a seawater flush, hydrate very quickly and disperse like water-based cuttings.

**Stock Limitations** on the base fluid are intended to encourage product substitution reflecting best available technology and best available demonstrated technology wherein only those synthetic materials and other base fluids which minimize potential loadings and toxicity may be discharged.

**PAH Content.** The EPA is regulating the polyaromatic hydrocarbon (PAH) content of base fluids because PAHs are comprised of toxic priority pollutants. SBF typically do not contain PAHs, whereas the traditional oil base fluids (OBF) of diesel and mineral oil typically contain 5 to 10% PAH and 0.35% PAH respectively. The PAHs typically found in diesel and mineral oil include: (1) the toxic priority pollutants fluorene, naphthalene, phenanthrene, and others; and (2) non-conventional pollutants such as alkylated benzenes and biphenyls.

**Sediment Toxicity.** EPA is also regulating the sediment toxicity in base fluids as a non-conventional pollutant parameter and as an indicator for toxic pollutants. It has been shown, during EPA's development of the Offshore Guidelines, that establishing limits on toxicity encourages the use of less toxic drilling fluids and additives.

**Biodegradation.** EPA is also regulating the biodegradation in base fluids as an indicator of the extent, in level and duration, of the toxic effect of toxic pollutants and non-conventional pollutants present in the base fluids Based

on results from seabed surveys at sites where various base fluids have been discharged with drill cuttings, EPA believes that the results from the three biodegradation tests used during the rulemaking (i.e., solid phase test, anaerobic closed bottle biodegradation test, respirometry biodegradation test) are indicative of the relative rates of biodegradation in the marine environment. In addition, EPA thinks the biodegradation parameter correlates strongly with the rate of recovery of the seabed where OBF- and SBF-cuttings have been discharged. The various base fluids vary widely in biodegradation rates, as measured by the three biodegradation methods. However, the relative ranking of the base fluids remain relatively similar across all three biodegradation tests.

The EPA also reviewed seabed surveys to identify potential impacts of SBM discharges on the seafloor. Early seafloor surveys were conducted by operators and service companies to confirm that discharge of SBM cuttings was not adversely impacting the environment. During the Coastal Effluent Limitation Guidelines development, a survey was conducted using an EPA research vessel. Finally, as part of the general permit, operators who were using SBMs were required to participate in a multi-well industry survey of SBM discharge sites. The general conclusions from these surveys indicated that SBM discharge impacts are limited to areas within 250 meters of the discharge point, that the organic phase of the drilling fluid biodegrades under seafloor conditions, and that the seafloor was recovering within a few years. In contrast to North Sea surveys, none of the surveys conducted in the Gulf of Mexico indicated that there were large piles of cuttings under the rig. In general, there were patchy distributions of cuttings near the rig in the Gulf of Mexico. As the seabed surveys were conducted before the widespread use of cuttings driers, the current discharge limitations for retention on cuttings are further reducing potential impacts on the seafloor compared to the discharges associated with the existing GOM seabed surveys.

### **North Sea**

In contrast to developments in the Gulf of Mexico, OSPAR decision 2000/3 eliminated the discharge of SBM cuttings.<sup>4</sup> Some of the specific statements made by OSPAR in their decision included the following:

- Recalling Article 5 of the OSPAR Convention which requires the contracting parties to take all possible steps to prevent and eliminate pollution from offshore sources in accordance with the provisions of the Convention in particular Annex III of the Convention.
- Noting that recently developed synthetic fluids are likely to persist when discharged into the marine environment at high concentration in drill cuttings where anaerobic conditions develop.
- Recognizing that marine pollution by drill cuttings and their associated organic phase fluids (OPF) should be avoided and prevented to the greatest extent possible.

Further review of documentation from the North Sea

indicates that the primary source of information that SBMs persisted was from a solid phase test conducted by the Scottish Office Agriculture, Environment and Fisheries Department (SOAEFD). During the period that SBM cuttings could be discharged, the primary criteria for base fluid acceptance was regulated by the test protocols in place at the time. These tests included toxicity tests on three species, aerobic biodegradation tests and bioaccumulation tests. The tests in use at the time were not specifically designed for base fluids and were plagued with broadly written protocols which resulted in high levels of test variability. In applying the tests to the wide range of available fluids, the market progression was toward the lowest cost base fluids that met the discharge criteria. In the case of the Norway section of the North Sea, an additional criteria was established that excluded base fluids that were not expected to biodegrade under anaerobic conditions. As time progressed, the UK sector of the North Sea migrated toward linear paraffins and linear alkyl benzene. In the Norway sector of the North Sea, base fluid use migrated toward linear alpha olefins.<sup>5</sup>

Seabed surveys were conducted on discharge sites in the North Sea for many years. In some cases these surveys identified large piles of cuttings under the discharge point. In a few cases the piles were over 5 meters tall.<sup>6</sup> As SBM discharges began, in many cases they were discharged on top of existing piles making it difficult to determine the fate of SBM cuttings. While cuttings driers were introduced into the North Sea market, they saw limited use and did not play a significant roll in the OSPAR 2000/3 decision. In the end, the decision to move away from SBM cuttings discharges was influenced by many factors. Some of the most likely major factors that resulted in the termination of SBM cuttings discharges included the following:

- Focus on historical cuttings piles and offshore discharges.
- Operators and service companies spoke with many conflicting voices.
- Variable test results led to degradation of base fluid environmental standards.
- Influence of Non-Governmental Organizations

Concurrent to the development of these two guidance documents and continuing forward, several other regions have been evolving their approaches to use and discharge of SBM and other non-aqueous drilling fluids (NAF). With many choices of fluids and sometimes conflicting information, engineers are sometimes assaulted with a flood of information about the technical, environmental, and economic performance of various base fluids. In order to provide a framework of understanding, the following paper is designed to unravel some of the confusing aspects of synthetic base fluids.

### Current Base Fluid Considerations

Experience has shown that the process of selecting, providing and servicing a particular base fluid product or type of base fluid is complex. Service companies fill a vital roll in

accessing the available base fluids and delivering them in a reliable manner. Base fluids are generally available to all service companies and while commercial agreements sometimes constrain supplies, most base fluids are available to multiple service companies; intellectual property rights impact supplies in a few cases including esters and linear paraffins manufactured using the Fisher-Tropsch process. Some of the key considerations in base fluid selection are listed in Table 1.

While there are many considerations, there are a few key drivers for base fluid selection which include the following:

First, **Technical Performance** is a very significant parameter in some cases. For example, in deepwater drilling environments, the drilling fluid is exposed to cold temperatures (40°F) for extended periods of time. In this case, temperature viscosity profiles are critical to ensure that the mud will not build excessive viscosity and turn to gel because of freeze point issues.

Secondly, **Environmental Regulation**, or definition, and H&S (health and safety) considerations serve as a critical acceptance criteria. The three primary environmental performance acceptance criteria for base fluids in most regions have been toxicity, biodegradation, and PAH. During the initial introduction and investigation of SBM technology in the North Sea, the focus was on base fluid quality; since the EPA issued their guidelines, there has been an equally strong focus on the quantity of base fluid retained on cuttings. While, laboratory acceptance criteria has been the most common way to control SBM discharges, the use of seafloor impact studies has been widely used to confirm that there are no long-term seafloor impacts from discharges of SBM cuttings. Consequently, the long-term acceptability of SBM discharges is primarily driven by continued documentation that the seafloor around SBM discharge sites does not suffer long-term impacts. In addition to environmental acceptance there are several other HSE issues, such as vapors and skin irritation, which exclude particular SBM base fluids if they cause problems.

The third major driver in SBM selection and use is **Cost**. In those cases where the cost of SBM use and discharge are lower than the alternatives – WBM, injection of cuttings, or hauling cuttings to the bank – then SBM is the technology of choice. However, as base fluid costs, and regulatory compliance cost increase, other technologies are favored.

In many areas, strictly defined legislation is not available to identify specific environmental performance criteria so operators are allowed to define their own criteria. In general, the higher performing base fluids are also the most expensive. Consequently, the level of environmental protection is a function of financial commitment. The relative cost between the basic criteria applied to base fluids and environmental performance is shown in Figure 1.

Because of general market conditions, operators balance two forces – cost and performance. First, the need to keep drilling costs down generally drives operators away from the highest cost fluids. Second, the need to show continuous improvement and environmentally acceptable performance drives operators away from the lowest cost base fluids.

Table 1 – Synthetic Considerations

Issue	Description	Impacts
Cost	Cost of base fluid is a critical issue because of the large volumes of base fluids used in the well.	Generally, the base fluids with the highest level of environmental performance cost more.
Technical	Synthetic base fluids have basic physical properties that are similar to mineral oils. However, synthetic fluids exhibit different temperature/pressure viscosity profiles and tolerance of contamination depending on chemistry.	Recognition of the optimum base fluid flow profiles is an important characteristic to evaluate when selecting base fluids for a region.
Definition of Synthetic	The definition of synthetic sometimes plays a key role in acceptance of a base fluid. The definition of synthetic can vary from region to region. Mature regulatory environments use a combination of definition and performance-based criteria.	Acceptance or rejection of a base fluid is a critical factor for the selection of a specific product or chemistry. Although the definition can be misleading, with respect to environmental impact, from a regulatory perspective, it is an easy avenue in the selection process.
Toxicity	Toxicity is used as a base fluid requirement and routine mud discharge requirement in the GOM. Understanding the test and the factors that influence pass/fail results are critical to compliance efforts.	Failure of a compliance requirement results in the rejection of a product or mud system.
Bioaccumulation	Bioaccumulation of certain organic chemicals is a known issue. SBMs are manufactured to exclude chemicals that are known to bioaccumulate.	Bioaccumulation and other sub-lethal environmental impacts are factors that influence acceptance or rejection of SBMs on a regional basis.
Biodegradation	Biodegradation is used as a base fluid requirement by the US EPA. Biodegradation was a critical factor in the elimination of SBM cuttings discharges in the North Sea. Aerobic and anaerobic degradation of synthetic base fluids is a major distinguishing factor between various base fluid chemistries.	Failure of a compliance requirement results in rejection of a product or mud system. Biodegradation rate is a significant factor in seafloor recovery which is a long-term product acceptability issue.
H&S	General H&S issues such as flashpoint and vapors are important acceptance criteria. The actual components of the vapors can contribute to overall assessment from an impact to H&S.	Service companies need to be aware of H&S issues associated with their products and work with operators and contractors effectively to prevent incidents
Skin Irritation	While SBMs themselves are not usually skin irritants, the mud system can be a skin irritant.	Service companies need to be aware of occupational health issues associated with their products and work with operators and contractors effectively to prevent skin irritation issues.
Regulators	Government regulatory agencies determine acceptance criteria and authorization of cuttings discharges.	Failure of a compliance requirement results in rejection of a product or mud system.
Internal Operator's Policy	Some operators, especially the major IOCs, already have internal policies which dictate or recommend the type of base fluid to be used according to either field application or government regulatory climate.	These policies sometimes make the decision for base fluid use very easy, but like many internal policies, the intent is present but the execution may be lacking. In this time of name branding and company integrity, more emphasis should be put on self-compliance than minimal compliance.
Sheen	The US EPA and many other regions have regulatory requirements that prohibit the discharge of effluents that sheen. There are product-related factors that influence the development of a rainbow colored sheen.	Successful SBM use and cuttings discharge requires a significant depth of experience and understanding of chemistry and related product issues. Service companies must be able to investigate and resolve all issues related to SBM use and cuttings discharge.
Supply Availability	Since synthetic fluids are manufactured and not refined, their availability is based on the manufacturing location, plant capacity and logistical limits of supply chains.	Supply availability is a significant factor in cost and reliability of a base fluid.
Intellectual Property Rights	In the case of a few base fluids, intellectual property rights drive product license agreements and can impact supply and cost.	Potential ability of one or more service companies to provide certain base fluids can be limited to eliminated due to legal restrictions from competitors.
Local content	In some areas, there is a contract requirement to include products with local content.	Local content issues can influence what products are favored in certain situations. In many cases, local content can cause the actual compliance process to take a local slant.

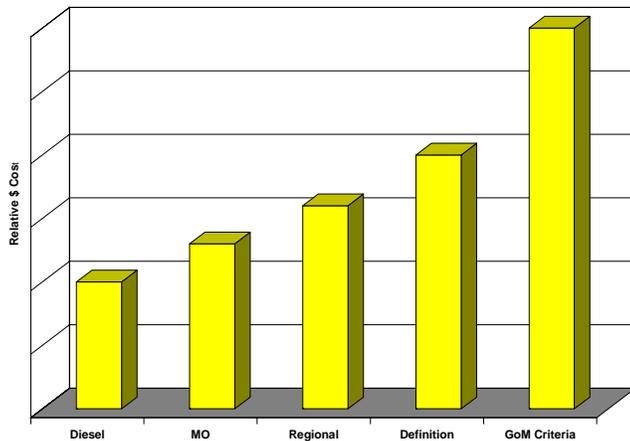


Fig. 1 – Relative cost of base fluids depending on compliance.

## Regional Developments for NAF Use and Discharge

### Gulf of Mexico

The US Gulf of Mexico has been one of the areas in which SBM use and SBM cuttings discharge has been developed. In the beginning, SBMs were used on the GOM shelf to address difficult wells that battled stuck pipe and hole washout due to reactive shales. Some operators have prohibitions against the use of oil-based mud offshore and consequently, SBMs began to displace OBM on a number of shelf wells. The high level of performance from SBMs allowed major deepwater drilling projects to be developed and became a significant technology factor in the ability to drill in deepwater. Significant resources were expended by industry and the EPA to develop appropriate environmental testing criteria and standards. These standards, which included a limitation on cuttings retention, were implemented in the general permit in February 2002. Since that time, SBMs have continued to be used on almost all deepwater projects (Figure 2). On the shelf, water-based muds (WBM) continue to dominate in most of the wells. As can be seen in Figure 3, after the General Permit was issued with new requirements for SBMs, the trend has been for shelf wells that need high performance to transition from SBMs to OBMs. The primary driver for transition from SBM to OBM is economics. The cost of the synthetic base fluid and associated compliance costs is higher than the cost of going to zero discharge and hauling the cuttings to shore. The acceptance criteria for base fluids in the US include sediment toxicity, anaerobic biodegradation and PAH. Both olefin and ester chemistry meet this criteria. However, because of the lower cost structure and higher drilling performance, olefins are used in most situations.

### North Sea

OBMs have become a dominating fluids technology. Cuttings are either injected or hauled back to shore for treatment and disposal. As discharge criteria have been eliminated as a concern, the dominating aspects of base fluid

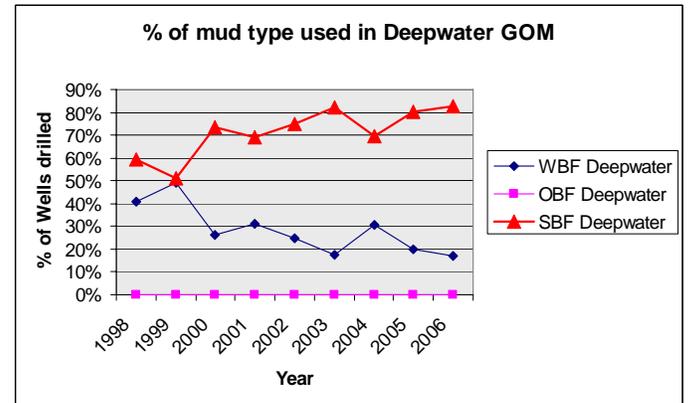


Fig. 2 – Type of mud used in deepwater Gulf of Mexico.

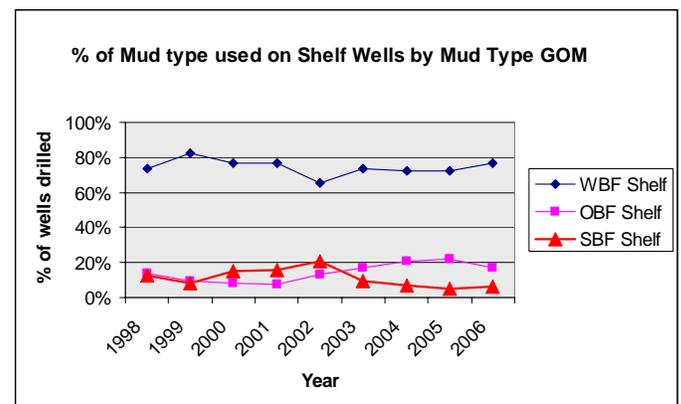


Fig. 3 – Drilling fluid used on GOM shelf wells grouped by type.

selection are occupational health exposures to base fluids, cost, and technical performance. Because of occupational health concerns, the predominant base fluids are ultra-clean mineral oils.

### South America

In South America, the general trend has been to allow controlled discharges of SBM cuttings. Acceptance criteria generally include toxicity and biodegradation and tend to use local species for toxicity tests. Both olefins and various paraffins (both refined and synthetic) have been used. In many cases international oil companies (IOCs) have chosen to use the Gulf of Mexico discharge criteria.

### West Africa

In West Africa, the general trend has been to allow controlled discharges of SBM and enhanced mineral oil cuttings. Acceptance criteria generally include meeting the definition of “synthetic” as defined on a local basis, in some cases, by the individual operator. The dominant base fluids have included those meeting the EPA definition of enhanced mineral oils. In some cases IOCs have chosen to use the Gulf of Mexico definition of synthetic which would include

synthetic paraffins but not enhanced mineral oils to minimize potential seafloor impacts.

### **Far East**

In the Far East, the general trend has been to allow controlled discharges of SBM cuttings. Their approach has been fragmented. Acceptance criteria generally includes toxicity and biodegradation and methodology tends to use local species for toxicity tests. Both olefins and synthetic paraffins have been used. In some cases IOCs have chosen to use the Gulf of Mexico discharge criteria that exclude paraffins. In Western Australia, linear alpha olefins have been the base fluids used the most. In Thailand, both synthetic paraffins and mineral oils are used.

### **Onshore**

Many of the same factors that drive base fluids selection offshore, also influence base fluid selection onshore. However, there are some key differences. Land spreading and bioremediation are major factors for onshore base fluid selection. This type of waste management favors synthetic linear paraffins. However, base fluid cost also dominates onshore because of the generally lower cost structures for onshore operations. In some areas such as western US, Western Canada and Mexico, diesel oil is commonly used as a base fluid for OBM. In many other areas, diesel has been replaced by mineral oil to reduce potential occupational health concerns.

### **Conclusions**

Base fluid selection and use has been an evolution of products and technology that has responded to general trends in slightly different ways. The assumption that all OBM and

SBMs would follow the North Sea and go to zero discharge has not occurred. The recognition that non-water quality impacts are also a concern has led many regions to continue to pursue controlled discharges as a regulatory option. The ability to continue to keep the onsite discharge open will depend on the ability of operators and service companies to continue to develop base fluids and solids-control equipment that minimize both the volume and impacts of discharges from SBMs.

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