The Application of Biodiesel as an Environmental Friendly Drilling Fluid to Drill Oil and Gas Wells

Abdul Razak Ismail[1*],NurulJannah Ismail[1], Mohd Zaidi Jaafar[1]and Ruhana Hassan[2]

[1]Petroleum Engineering Department,
Faculty of Petroleum and Renewable Energy Engineering,
UniversitiTeknologi Malaysia,
81300 Johor Bahru, Johor, Malaysia.

[2]Department of Aquatic Science,
Faculty of Resource Science and Technology,
Universiti Malaysia Sarawak,
94300 Kota Samarahan, Sarawak, Malaysia.
*Corresponding Author : razak@utm.my

ABSTRACT

The oil and gas industries need to use oil based drilling fluids to drill troublesome rock layers such as sensitive shale formation or to drill very deep oil and gas wells. However, using oil based drilling fluids will create pollution and therefore, environmental regulations on discharge of such drilling fluids have become more stringent because it will give tremendous impacts on the marine life and ecosystem. This research is conducted to formulate a new environmental friendly drilling fluids using vegetable oils derived biodiesel to replace the oil based drilling fluids without reducing their performances. This study focuses on physical properties and biodegradation rate of biodiesel based drilling fluids with respect to its toxicity and compare with the conventional oil based drilling fluids. Several biodiesels which derived from vegetables oils such as palm oil, corn oil and rice bran oil have been used as base oil in formulating ester based drilling fluids. Acute toxicity test and biodegradation test using closed bottle method were tested using local fishes. The result showed that almost all vegetable oils achieve the required physical properties. However, rice bran oil is almost non-toxic since their 50% lethal concentration (LC_{50}) value is felt in the range of 10,000 to 100,000ppm. Besides, rice bran oil is found to be easily degraded as it showed about 80% of biodegradation rate within 28 days. Therefore, rice bran oil drilling fluid offer the best solution in solving the environmental standards compared to other vegetables oils.

Keyword: environmental, biodiesel, drilling fluids

1. INTRODUCTION

The rising of global energy demand has led to exploration for oil and gas in increasingly difficult environments. Exploration is now extending into sensitive areas, in particular, offshore field.

The development of deep and ultra-deep offshore operations brings new and more complex technical challenges due to the harsh conditions encountered at these water depths. To encounter this challenges, oil based drilling fluid are much prefered to be used for drilling in this condition because it performs better than water based drilling fluid [1,2].

Oil-based drilling fluid are among the best performant and cost effective fluids in hostile conditions. They are used in particular when drilling water-sensitive shale, or when high temperatures are encountered, risk of important differential pressure sticking, exposure to acid gas, or long directional intervals requiring minimum torque and drag on the drill string. Even though they may be two or three times more expensive than water based drilling fluids, their use is justified by better performances and savings on mud maintenance.

During the last decade, environmental regulations have severely restricted the use of conventional oil-based drilling fluids, mainly because of their impact in marine environment during offshore operations. All these general environment concerns have led to an extensive industrial research aiming at designing non-toxic substitution fluids that could replace conventional oil based drilling fluids but have the same performances in a wide range of drilling conditions.

Biodiesel were first field trialled offshore Norway [3] and been used to drill several hundred wells since that time [4]. Biodiesel based drilling fluids have had limited success in field applications. They generally have higher kinematic viscosity, which translates into higher drilling fluid rheological properties.

High rheological properties limit the ability of biodiesel based fluids to tolerate high solids loading at higher fluid density. To take into account, biodiesel are also much more aggressive to elastomer components used in downhole drilling and completion equipment.

Additionally, they are susceptible to hydrolysis. Hydrolysis, the reaction of ester with water to produce carboxylic acid and alcohol, increases in rate at higher temperatures and increased by the presence of alkalinity agents such as lime.

However, biodiesel have some advantages over these base oil alternatives in terms of biodegradation and toxicity. This made biodiesel as one of the best alternatives to produce the suitable drilling fluid that satisfies both technical and environmental criteria. To meet this both criteria, the industry has recognized the potential of vegetable oil derived biodiesel based mud. To overcome several drawbacks of vegetable oil, good drilling fluid formulation could be suggested for efficient oil-based drilling fluid [5]. Table 1 shows the toxicity rating classification system adopted by other researchers.

Table 1. Toxicity rating classification system[6]

Category	Concentration (LC_{50})
Non toxic	> 100,000ppm
Almost non toxic	10,000 – 100,000ppm
Slightly toxic	1,000 – 10,000 ppm
Moderately toxic	100 – 1,000ppm
Toxic	1– 100ppm
Very toxic	< 1ppm

2. METHODS

Fish samples

Two species of brackish water-tolerate fish were chosen for this test (Figure 1). Juvenile of seabass (*Latescalcarifer)* and juvenile of red snapper (*Tilapia niloticus)* were selected as the test species for tropical environment for several reasons including its ready availability throughout the year, ease of upkeep in laboratory, convenience for testing, common presence throughout the country and previous experience [7] confirming its suitability for eco-toxicity testing as per the OECD Guidelines for Testing of Chemicals (1992).

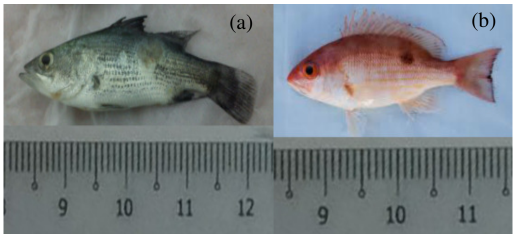

Figure 1. Juvenile of brackish water-tolerate fishes (a) Seabass (*Latescalcarifer)* and (b) Red snapper (*Tilapia niloticus).*

Drilling fluid samples

Several types of vegetable oils such as palm oil, corn oil and rice bran oil were selected as the based drilling fluid. The performance of these vegetable oils will be compared with commercially used drilling fluids such as diesel and sarapar.

The vegetable oils were converted to biodiesel through trans-esterification, where alkaline catalyst was used. The physical properties of biodiesel (kinematic viscosity, density, pour point and flash point) were determined.

The biodiesels were then used as base fluid to formulate drilling fluids. Table 2 shows the formulation of the vegetable oil drilling fluids. The fluids were tested for their toxicity level and degradation rate.

Table 2.Formulation of the biodiesel drilling fluid

Component	Quantity	Function
Biodiesel	85 ml	Base fluid
Distilled water	175 ml	Base fluid
Calcium chloride ($CaCl_2$)	25 g	Water activity and density
Confimul P	3 ml	Primary emulsifier
Confimul S	5 ml	Secondary emulsifier
Lime	1 g	Producing alkaline medium
Versatrol	10 g	Fluid loss control agent
VG-69	2 g	Gel forming agent (viscosifier)
Barite	250 g	Weighting agent

Test method

For toxicity test, the juveniles of seabass and red snapper (about 2-5cm long) were used in this study. The fishes were collected from Fisheries Research Institute, Gelang Patah, Johor, Malaysia.

The fishes were then acclimatized for a week prior to the test. During the acclimatization period, temperature, dissolve oxygen (DO) concentration, pH, presence of light were monitored and they were fed twice daily using commercial pellets.

Five different concentrations of drilling fluids of 10,000ppm, 15,000ppm, 25,000ppm, 50,000ppm, 75,000ppm and a control test chamber were exposed to the juvenile of seabass and red snapper in a static system with aeration. The conditions of the fish were observed after 24, 48, 72 and 96 hours.

Fish were considered dead if no discernible movement were observed and no reaction of caudal peduncle if touching. Mortalities and *in-situ* water parameters were recorded daily. The LC_{50} value of this test was analyzed using Probit analysis.

For biodegradability, the test was performed according to the standard method OECD 301D Closed Bottle Test (1992).

Two mg of drilling fluids (test substance) in 1liter nutrient medium was inoculated with microorganisms from the natural occurring seawater and kept in completely full, closed bottle in the dark condition at constant temperature.

The biodegradation was calculated based on the dissolved oxygen of the test solution over 28-days period. The amount of oxygen taken up by the microbial population during biodegradation of the test substance, corrected for uptake by the blank inoculum run in parallel, was expressed as the percentage THOD (theoretical oxygen demand).

The dissolved oxygen of the samples was measured every four days (in duplicate)for construction of the biodegradation curve.

3. RESULTS

Prior to formulate the acceptable rheological properties of drilling fluids, it is vital to have base oil which meets the minimum requirements in terms of viscosity, density, flash point and pour point.

Five types of base oil were evaluated based on ASTM D6751 *Standard Testing for Biodiesel Production* prior to formulating them as the drilling fluids. The results are shown in Table 3.

Table 3. Physical properties of base oil

	Kinematic viscosity @ 40 □C (cSt)	Den-sity (g/ml)	Flash point (□C)	Pour point (□C)
Base oil required properties	1.9 – 6.0	-	> 66	<ambient temp.
Diesel	3.97	0.86	71	3
Sarapar	2.65	0.76	122	9
Palm oil methyl ester (POME)	5.25	0.87	178	6
Corn oil derived biodiesel (CODB)	6.18	0.93	87	0
Rice bran oil derived biodiesel (RBODB)	4.68	0.89	188	-3

Toxicity test

Table 4 shows the LC_{50} value of various drilling fluids on the fishes. In general, mortality rate of both fishes was increased gradually with the increase of concentration of test substances.

Table 4. LC_{50} value of drilling fluids on juvenile of seabassand red snapper

Drilling fluids	Juvenile of seabass[1]	Juvenile of red snapper[1]
Diesel	5,800 ppm	7,080ppm
Sarapar	8,700 ppm	10,700ppm
Palm oil metyl ester (POME)	28,800 ppm	22,900ppm
Corn oil derived biodiesel (CODB)	35,400 ppm	33,800ppm
Rice bran oil derived biodiesel (RBODB)	40,700 ppm	39,000ppm

[1]Mean value of triplicate tests

Diesel drilling fluid shows the highest mortality rate (even when exposed to low concentration) for both fishes. The second highest mortality rate can be seen from sarapar drilling fluid with slightly higher concentration compared to diesel drilling fluid.LC_{50} value for diesel and sarapar give a value of 5,800 ppm and 7,080ppm for juvenile seabass and 8,700 ppm and 10,700ppm for juvenile red snapper respectively.

Table 4 also shows that all of ester based drilling fluids give good results. All ester based drilling fluids were having LC_{50} more than 10,000ppm. The highest LC_{50}values of 40,700 ppm and 39,000 ppm were recorded by rice bran oil derived biodiesel (RBODB) based drilling fluids for both juvenile seabass and red snapper respectively.

Therefore, these tests confirmed that all of the biodiesel based drilling fluids tested were categorized as almost non-toxic substances as their LC_{50} value were ranged between 10,000ppm to 100,000ppm (according to Table 1).

Degradation test

Degradation percentage of the drilling fluids can be seen as in Figure 1. Based on the graph, almost all biodiesel based drilling fluids have high biodegradation rate as they achieve the acceptable percentage of 60% after 28 days. Diesel and sarapar based drilling fluids showed low percentage of degradation which indicates that both of them were not easily degrade in natural seawater due to their high aromatic content.

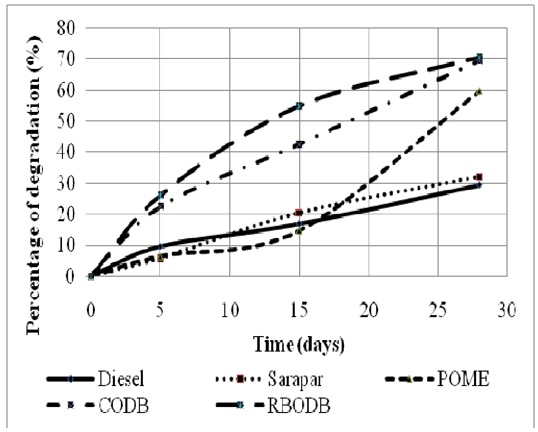

Fig. 2. Percentage of degradation of different drilling fluids over 28 days

A comparison between biodiesel based drilling fluids was also studied. From the graph obtained in Figure 2, it shows that rice bran oil derived biodiesel (RBODB) and corn oil derived biodiesel (CODB)had consistent degradation compared to palm oil metyl ester (POME)which great degradation was occurred after day 15.

Upon completion on this test, all of the ester based drilling fluids were achieved at least 60% of degradation. The reasons is because esters have low aromatic content and low degree of branching which enable them to have fast degradation rate.

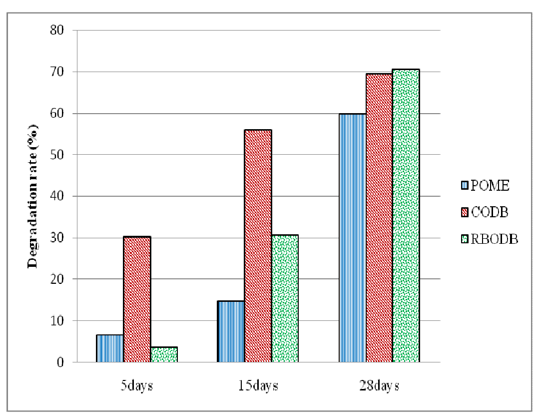

Fig. 3 Comparison on degradation of different biodiesel based drilling fluids over 28 days

4. CONCLUSION

Biodiesel based drilling fluids can be considered as environmental friendly drilling fluids which may not cause harmful threat to the marine organisms in the drilling area with respects to their level of toxicity and degradation rate.

Therefore, the environmental effect regarding marine ecosystem could be reduced by substituting commercial used oil based drilling fluid with biodiesel based drilling fluids with certain limitations.

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