TOXICITY STUDY ON MARINE ORGANISMS DUE TO DRILLING FLUIDS

Abdul Razak Ismail
Noor Jana Ahmad
Muhd. Noorul Anam

Faculty of Chemical & Natural Resources Engineering
Universiti Teknologi Malaysia
80990 Johor Bahru, Malaysia

Abstract

Drilling fluids or usually known as drilling muds must be used to drill oil or gas wells. Two types of muds that are normally used in drilling operation are water based muds and oil based muds (diesel and mineral oil). Drilling muds are complex mixtures which contain many types of additives and chemicals which may pollute the environment if necessary precautions are ignored. Because of this effect, many countries have introduced certain regulation to control this problem.

Studies have been conducted to evaluate the toxicity effects of the three drilling fluid systems to marine life. The toxicity tests were carried out using local marine species namely tiger prawn *(Penaeus Monodon)* for the suspended particle phase of the drilling fluid systems and cockle *(Anadara Granosa L.)* for the solid phase of the drilling fluid systems.

Results show that the oil based mud (diesel) caused the highest mortality of tiger prawn during the 96 hours of the toxicity test. The results also suggest that the lower concentration of suspended particle phase from the oil based mud (diesel) can kill 50% of tiger prawn in the range of 300 ppm compared to the oil based mud (mineral oil) which is in the range of 600 to 700 ppm and water based mud (5000 to 6000 ppm). However, for the solid particle test, water based mud shows higher toxicity compared to the ok based muds (diesel and mineral oil). Ten days exposure of cockle to the solid phase sample shows that water based mud indicates the highest mortality (87%) compared to the oil based mud (diesel) which is 73% and oil based mud (mineral oil) which is 53%. These results suggest that drilling fluid systems should be carefully formulated to minimize the effect of pollution to the environment.

Introduction

Drilling muds are complex mixture which contain many types of additives and chemicals with one kind of base fluid for example water or oil. Drilling muds serve several important functions: carry cuttings to the surface for disposal, cool and clean the bit, maintain pressure balance between the geological formation and the bore hole, lubricate the bit, reduce friction in the borehole, seal permeable formations, stabilize the borehole and etc.[1] Two types of muds that are normally used in drilling operation are water based mud and oil based muds.

Water Based Mud (WBM)

WBMs are by far the most commonly used muds, both onshore and offshore. WBMs are widely used in shallow wells and often in shallower portions of deeper wells, but often are not effective in deeper well and extended-reach wells. The uses of WBMs generate 7,000 to 13,000 bbl of waste per well. Depending on the depth and diameter of the well, about 1,400 to 2,800 bbl of that amount are drill cuttings.[2] WBMs use water as their base fluid and does not contain any oil. WBMs are very economical and easy to dispose of because they can be fully biodegraded and considered as very low toxicity. In most cases, both the WBMs and the cuttings are discharged on site to the ocean. There is no sound regulation in discharging WBM or WBM cuttings.

The performances of WBMs are deficient for some applications, particularly in drilling high angle wells, extended-reach well, or in high temperature and hydratable shales. Despite of its excellent environmental friendly, cheap, and easy to dispose of, WBMs have limitations for some applications. The use of WBMs is more economical in drilling many shallow wells, and WBMs will continue to be used in those instances.

Oil-Based Mud (OBM)

During the past 30 years, OBMs have been developed and refined to overcome the limitation of WBMs applications. OBMs have traditionally been used to improve lubricity, minimize problems associated with water sensitive formation, and addressed other site specific conditions, such as temperature, for which WBMs are not well suited.

OBMs have been the mud of choice for a range of special situations, including high temperatures, hydratable shales, high angle and extended-reach well, high density mud, and drilling through salt. Wells drilled with OBMs normally produced lower waste volume than those drill with WBMs because very little slumping or caving in of the walls of the hole occurs. Also, a nearly gauge hole is drilled, and the mud is reconditioned and reused rather than discharged at the end of the well. Only the drill cuttings will be disposed of. The average volume of OBM waste (drill cuttings with OBMs adhering to the cuttings) is estimated at 2,000 to 8,000 bbl per well.[2]

The base fluids of OBM are normally either diesel or mineral oil, even though nowadays many other types of low toxicity oil are developed. Because they contain oil, OBMs waste cannot be discharged on site under the Effluent Limitation Guidelines (ELGs) a discharging law by Environmental Protection Agency (EPA). ELGs prohibit releases of free oil, as detected by the static sheen test, from drilling fluid and drill cuttings discharges.

Discharge of OBM cutting posses a greater environmental impact on the sea floor than does discharge of WBM cuttings. OBM cuttings are significantly increase oil content in sediment and decrease biological abundance and diversity of immobile bottom-dwelling organism in the affected area.

The United Kingdom Department of Energy has set a few guidelines for discharging off toxic chemical and drilling fluids. The UK guidelines for acceptability of a mineral oil based mud call for the mud system to exhibit 96 hours LC50 > 10,000 mg/l (ppm) and the base oil must exhibit 96 hours LC50 > 1,000 mg/l (ppm). 96 hours LC50 is a standard test to determined the concentration of the substance which will prove lethal to 50% of a test population of the marine organism in 96 hours.[3] Despite the unique and valuable properties of OBMs, their uses are limited because of their toxicity.

Toxicity Tests

Two phase toxicity studies were conducted to evaluate the toxicity of WBM, OBM (diesel) and OBM (mineral oil). The two phases are suspended particle phase and solid phase. Suspended Particle Phase (SPP) and Solid Phase (SP) of the drilling fluid system were introduced in the test to simulate the real phenomena when the drilling fluids were disposed of into the sea. The formulation used for the WBM, OBM (diesel) and OBM (mineral oil) can be identified in Tables 1 and 2.

As a first phase of toxicity testing, SPPs of the WBM, OBM (diesel) and OBM (mineral oil) were tested for 96-hour LC50 acute toxicity to compare the toxicity of the three base fluids (water, diesel and mineral oil). Before testing, each drilling fluid systems was combined with sea water in a 1:9 volumetric ratio. The mixtures were stirred for 30 minutes and then allowed to settle for 1 hour. The SPPs were then separated from the SPs and used for the toxicity test. The tests were conducted according to the basic procedures of API RP 13H.[4]

These tests were carried out using local marine species namely tiger prawn (*Penaeus Monodon*). Ten tiger prawns were exposed to various concentrations of the SPP to determine 96-hours LC50 concentration of WBM, OBM (diesel) and OBM (mineral oil) plus one control sediment for each set of test.

The second phase of the toxicity test was conducted to compare the acute toxicity of the SPs of WBM, OBM (diesel) and OBM (mineral oil). In this test, local cockles (*Anadara Granosa L.*) were selected as test organisms. Ten cockles were exposed for 10 days to each SP of the test materials plus a control sediment. These toxicity tests were conducted according to the basic procedures of API RP 13B.[5] Both, the first phase and the second phase of the tests were done in three-replicates to get more dependable results.

Results and Discussion

Some of the results from 96 hours LC50 toxicity tests are presented in Fig. 1, 2 and 3 for WBM, OBM (diesel) and OBM (mineral oil) respectively. These figures illustrate that at a same concentration and a same period of time for each test material, OBM (diesel) have caused the highest mortality percentage to tiger prawn compared to WBM and OBM (mineral oil). OBM (diesel) have caused the death of 50% tiger prawn in 65 hours at a concentration of 600 ppm and took only 25 hours to do so at a concentration of 1000 ppm. While WBM showed the highest survival percentage of the tiger prawn for the same conditions.

The lethal concentrations were obtained from Fig. 4, 5 and 6 for WBM, OBM (diesel) and OBM (mineral oil) respectively. The lethal concentrations were determined direct from the plot and the ranges were obtained from the three replicates.

Both OBM (diesel and mineral oil) showed LC50 value much lower compared to WBM. OBM (diesel) showed a LC50 around 300 ppm (i.e.50% of tiger prawn survived at a concentration of 300 ppm SPP of diesel). The LC50 for OBM (mineral oil) are in the range of 600 to 700 ppm while the LC50 for WBM are in the range of 5000 ppm to 6000 ppm. Based on these toxicity tests, WBMs are far less toxic than OBM (mineral oil) which is about twice less toxic than OBM (diesel).

The solid phase toxicity tests provided completely different results from the suspended particle phase. Based on the results on Fig. 7, OBM (mineral oil) demonstrated the highest survival percentage of the cockles after 10 days exposure to the SP of the test samples. The average survival percentage from three replicates was 47% for OBM (mineral oil), while OBM (diesel) showed second highest average survival percentage with 27%. WBM was the most toxic in the solid phase after 10 days exposure with an average of only 13% of the cockles survived. The main factors contributing to the high toxicity phenomena in WBM solid phase were its solid components like foralyst and resinex which most probably were toxic.

Conclusion

1. On suspended particle phase 96 hours toxicity tests OBM (diesel) has proved to be the most toxic. This toxicity was due mainly to its base oil that was diesel. This was proved because the formulation of OBM (diesel) and OBM (mineral oil) were exactly the same, except the base fluid (diesel or mineral oil).

2. WBM was the least toxic in the suspended particle phase but indicates the highest mortality (87%) compared to OBM (diesel) which is 73% mortality and OBM (mineral oil) which is 53% mortality in the solid phase.

3. Besides the toxicity of the based fluid, certain additives like foralyst and resinex can also contribute to toxicity and pollution to the environment.

References

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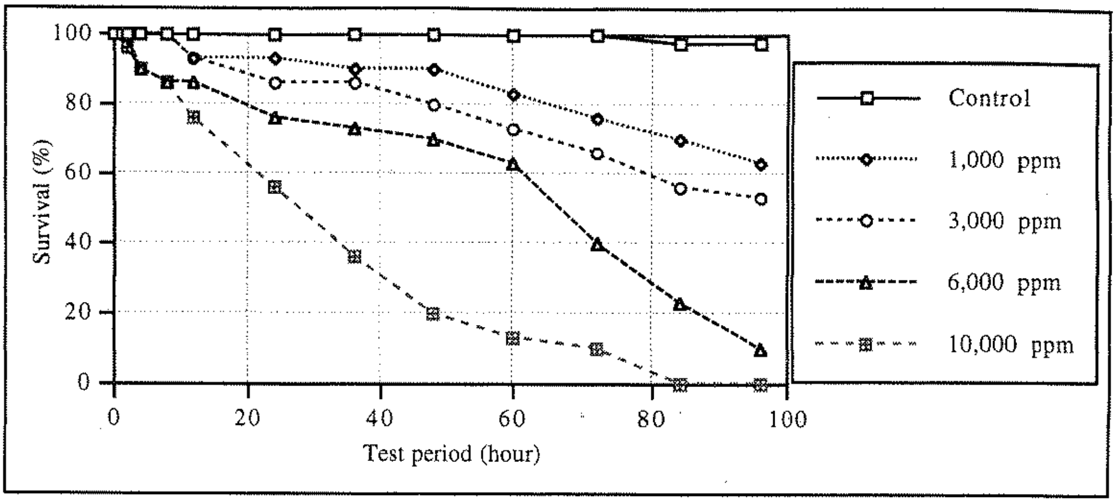

Fig. 1 - Average survival of tiger prawn for water-based mud.

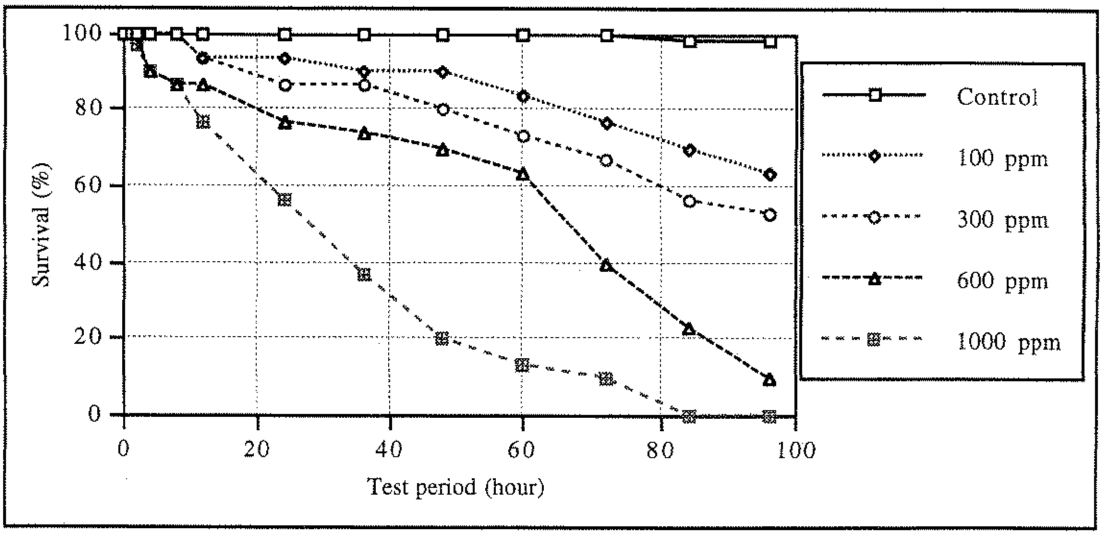

Fig. 2 - Average survival of tiger prawn for oil-based mud (diesel).

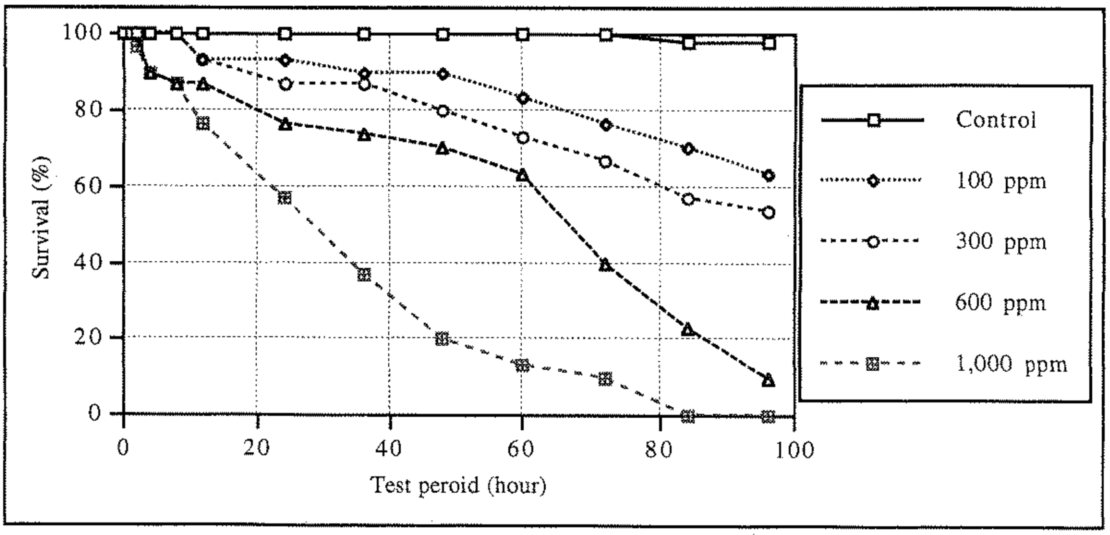

Fig. 3 - Average survival of tiger prawn for oil-based mud (mineral oil).

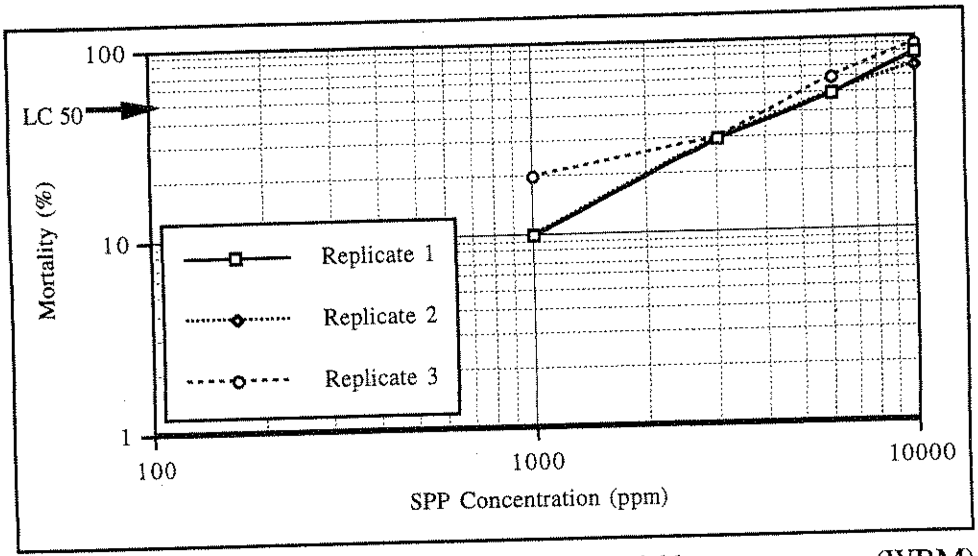

Fig. 4 - Mortality percentage of tiger prawn after 96 hours exposure (WBM).

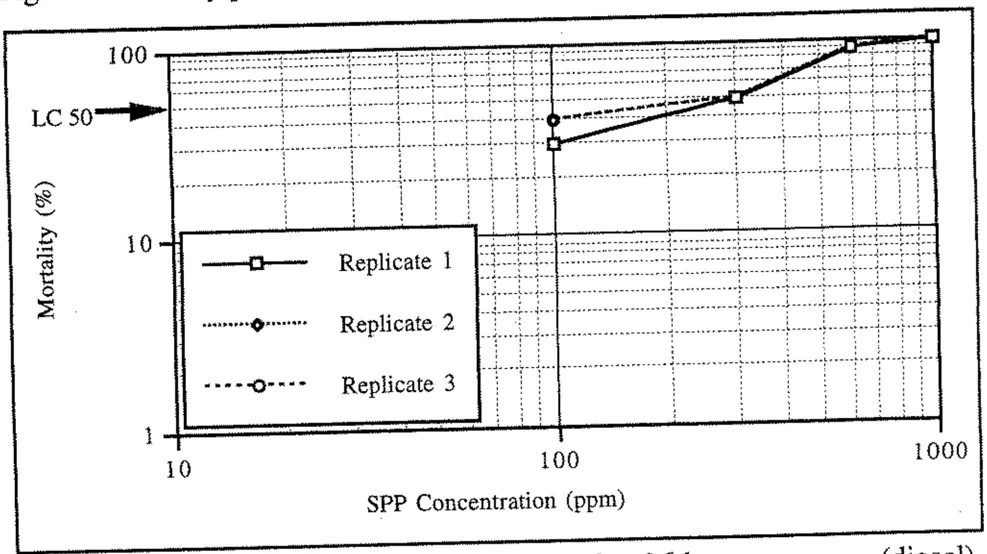

Fig. 5 - Mortality percentage of tiger prawn after 96 hours exposure (diesel).

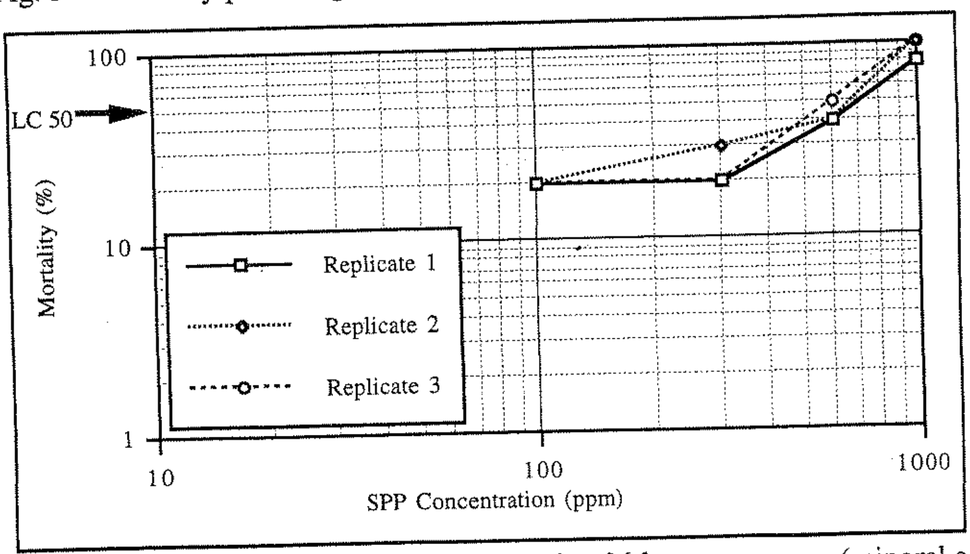

Fig. 6 - Mortality percentage of tiger prawn after 96 hours exposure (mineral oil).

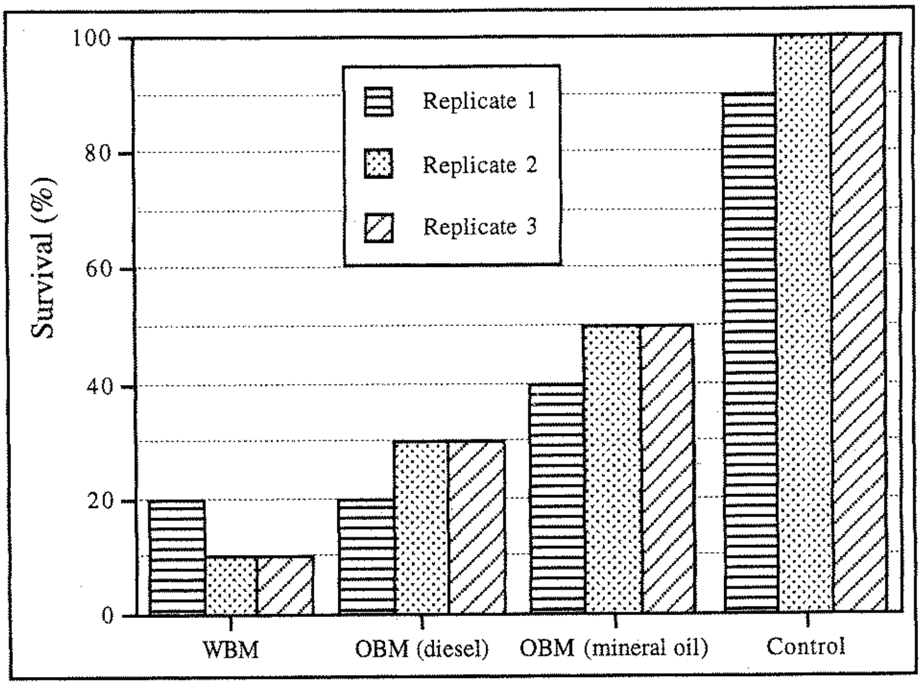

Fig. 7 - Survival percentage of cockles after 10 days exposure to SP of drilling mud.

Table 1. Water base mud formulation

Component	Quantity
Water, ml	350
Caustic soda, g	0.25
Soda ash, g	0.8
KCl, g	40
Pac R, g	1
Pal UL, g	1
Foralyst, g	3
Resinex, g	4
Barite, g	103

Table 2 - Oil base mud formulation

Component	Quantity	
	Mineral oil	Diesel
Base fluid (mineral,diesel), ml	350	350
Main emulsifier, g	10	10
Secondary emulsifier, g	8	8
Lime, g	5	5
Filtration agent, g	6	6
Viscosifier, g	5	5
Wetting agent, g	2	2
Water, ml	49	49
$CaCl_2$, g	15	15
Barite, g	155	180