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Comparative toxicity of drilling fluids to marine water shrimp (Mysidoposis bahia) and brackish water shrimp (Palaemonetes africanus)

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***Abstract**: The comparative toxicity of drilling fluids; Addax-WBF (water base) and Addax-OBF (oil base) to marine water shrimp (Mysidoposis bahia) and brackish water shrimp (Palaemonetes africanus) were examined, The static with renewal option for acute toxicity assessment at concentrations 0, 10, 100, 1000, 10000 and 100000ppm was employed. Mortality of the shrimps (LC_{50}) was used as indices to monitor toxicity. The 96h LC_{50} of the drilling fluids were, Mysidoposis bahia [Addax-OBF base in marine water] (9098mg/L) > Mysidoposis bahia [Addax-OBF oil base in brackish water] (24130mg/L) > Palaemonetes africanus [Addax-WBF water base in marine water] (28000ppm) > Palaemonetes africanus [Addax-WBF water base brackish water] (47260ppm) (noting; the lesser the LC_{50} the more toxic the toxicant). Comparatively, marine water shrimp (Mysidoposis bahia) is more susceptible than brackish water shrimp (Palaemonetes africanus) to both water- and oil-base drilling fluids. Comparatively, oil-based fluid was toxic to the test organisms while water-based fluid was less toxic to the test organisms. Oil base drilling fluid Addax-OBF to Mysidoposis bahia in marine water showed the highest level of toxicity (LC_{50} 9098ppm). The test organisms displayed similar levels of sensitivities to the two fluids at 95% probability levels. Based on these findings in this study the use of oil-based fluids should be discouraged during drilling operation associated with Petroleum, industry in the Niger Delta. Thus in the marine and brackish water environment of the Niger Delta were a lot of exploration and production activities in the petroleum sector are concentrated, the use of water-based drilling fluids should be encouraged because of their environmentally friendly (ease of biodegradation and non toxic) properties. More so, since these shrimps have perfect resistance against pollution of drilling fluids up to 10,000ppm, this study findings indicated that Mysidoposis bahia and Palaemonetes africanus could be used for toxicity tracing drilling fluid in marine and brackish water.*

***Key words;** Drilling fluid, Toxicity, Static*

I. Introduction

Drilling fluids went through major technological evolution, since the first operations performed in the US, using a simple mixture of water and clays, to complex mixtures of various specific organic and inorganic products used nowadays. These products improve fluid rheological properties and filtration capability, allowing penetrating heterogeneous geological formations under the best conditions (Schlemmer et al., 2002) but the negative environmental impact is on daily toll increase, Estuaries are highly sensitive zones subjected to the heavy industrialization and overpopulation (Venkatachalapathy et al., 2010). The individual components of the chemical additives in the mud may pose toxicity problems (Terrens et al 1998). The complexity of the problems met in petroleum drilling has led to emerging techniques for the formulation of appropriate fluids. There are two main types of drilling fluids: Water base fluid and Oil base fluid. Generally, drilling mud (fluids) may be classified in the following three families:

1. The WBM family, in which fresh-, salt-, or sea-water is the continuous phase, is the most used (90-95%). The WBM are mainly composed of aqueous solutions of polymers and clays in water or brines, with different types of additives incorporated to the aqueous solution.
2. The OBM family is less used (5-10%). These drilling fluids have been developed for situations where WBM were found inadequate (Chilingarian and Vorabutr, 1981). The OBM are oil- (usually, gas oil-) based muds. Generally, they are invert emulsions of brine into an oil major, continuous phase stabilized by surfactants. Also, other additives are often added to the organic phase, such as organophilic modifiers of the clay surface. However, although OBM often give better performances, they have major drawbacks such as to be generally more expensive and less ecologically friendly than WBM. Consequently, although OBM give greater shale stability than WBM (Bol et al., 1992), these latter systems have also been developed by many researchers in order to respond to environmental regulations (Schlemmer et al., 2002).
3. The third family of drilling fluids comprises gas, aerated muds (classical muds with nitrogen) or aqueous foams (Coussot et al., 2004). These drilling fluids are used when their pressure is lower than that exerted by the petroleum located in the pores of the rock formation. These fluids are called ‘underbalanced fluids’.

This underbalanced drilling technology is generally adopted for poorly consolidated and/or fractured formations.

Several substances or waste materials introduced in to the environment as a result of petroleum exploration activities may be toxic and persist in their immediate environments. These toxic effects may be acute or chronic (Rhodes and Hendricks 1990; Okpokwasili and Odokuma 1996), while some may stimulate growth (Okpokwasili and Odokuma 1994). In the Nigerian oil industry both water-based and oil- based mud systems are employed in oil drilling operations. Oil-based mud systems are especially used during directional drilling for oil and gas (Ifeadi et al., 1985). In Nigeria drilling muds and cuttings are normally discharged into fills and from here they overflow into nearby farms and rivers. These drilling muds discharged untreated into the environment, generally may have adverse affects on the ecosystem. During drilling, plumes (muddy) of turbid water are commonly seen trailing down stream from the drilling platform (Jack et al., 1985). Drilling mud (drilling wastes) are sometimes unintentionally or intentionally released into water bodies and can damage the gills of prawn, shrimp and other bottom dwellers at post larvae stages. For most aquatic animals, the gills are major sites through which waterborne pollutants can enter the body and are often affected by such substances (Ekundayo and Benka-Coker, 1994; Soegianto et al., 2008). The toxic effect could be due to the paraformaldehyde biocides and heavy metals included in the different mud formulations / composition, which increases the toxicity to aquatic species especially bottom dwellers (Sorbye, 1989; Patin, 1999). Acute (short-term) and chronic (long-term) health impacts can occur through bioaccumulation of oil, metals and other products in aquatic species that are consumed by humans. In many countries, muds and cuttings are discharged on site into the ocean. However, the regulators in Nigeria [Federal Ministry of Environment (FME) and Department of Petroleum Resources (DPR)] require that a toxicity test be conducted on any drilling mud to ascertain their safety before release into the environment or deep wells (DPR, 2002; FEPA, 1991). The lethal concentration (LC50) is a standard toxicity test to determine the concentration of the substance which will prove lethal to 50% of a test population of the organism in a specified duration (Burke and Veil, 1995; Landis and Yu, 2004). The aim of this study was to estimate the short-term toxicity of oil-based drilling mud (drilling wastes) on shrimp (Palaemonetes africanus) in the brackish water environment. These organisms were chosen because they produce consistent and reproducible response to toxicants and could be transported and maintained in the laboratory with relative ease. They are also principle prey of many larger vertebrates (Ciarelli et al., 1997).

In the Niger Delta the use of drilling fluids during operations is a common practice and their use poses a lot of stress to the environment. Thus the objective of this study was to assess the toxicity of two main classes of drilling fluids commonly employed in drilling operations in the Niger Delta in Nigeria to two test organisms'(Mysidoposis bahia and Palaemonetes africanus) representative of aquatic food chains in the marine and brackish water environment of the Niger Delta in Nigeria.

II. Materials And Methods

DRILLING FLUIDS Drilling muds employed in this study were of two types the water- based and Oil-based drilling fluids; obtained from Addax Petroleum Development Company, Nigeria.

SOURCE OF TEST ORGANISMS Mysidoposis bahia marine water shrimp were obtained from Bonny Island, Bonny, Nigeria. Palaemonetes africanus brackish water shrimp were obtained from Trans – Amadi Industrial Layout, Port Harcourt Nigeria.

Juvenile shrimps of fairly equal size were randomly caught with a hand net of mesh 0.5mm and transferred into the test vessel. The shrimps were not touched with hand during the selection so as to avoid stress due to handling only active and healthy shrimps were selected.

Average weight per organism:

Mysidoposis bahia (marine water)	=	151 ± 5mg
Palaemonetes africanus (brackish water)	=	167 ± 5mg

Average length of test species were recorded as

Mysidoposis bahia (marine water)	=	1.9 ± 0.5cm
Palaemonetes africanus (brackish water)	=	2.7 ± 0.5cm

Acclimatization: The test organisms were acclimatized separately in glass tanks shortly after sampling at room temperature for ten days. The water in the acclimatization units was replaced with water from the organism's habitat water once daily. A maximum of fifty organisms were kept in each tank. This number was kept like this to prevent crowding. The dimensions of holding tanks were 2 x 6 x 6m.

Toxicity Testing: The test vessels had the following dimensions, 1m x 1m x 1m. The vessels were wrapped with dark polyethylene. The vessels contained marine water from Bonny River and brackish water from Trans-Amadi River for shrimps. Six logarithmic concentrations of the test chemicals; 0, 10, 100, 1000, 10000 and 100000 were prepared using water from the habitat of the test organism, as diluents. A preliminary range finding test was first performed before these concentrations were arrived at. The 96h acute toxicity bioassay was carried out on Mysidoposis bahia and Palaemonetes africanus using the procedure of APHA (1998). Seven different toxicant concentrations 0, 10, 100, 1000, 10000 and 100000ppm were prepared for the experiment with controls of filtered clean water from the habitat of the test organisms (dilution water). Ten shrimps of fairly equal sizes were randomly caught with hand net and carefully transferred into each test vessel. The organisms were not touched with hand during the selection so as to avoid stress due to handling. Only healthy and active organism was selected.

Mortality was recorded after 4, 8, 12, 24, 48, 72 and 96 hours. Dead shrimps were removed at each observation. Mortality was plotted against the concentration on a log graph. Regression analysis was used to obtain the line of best fit. To obtain the median lethal concentration (LC_{50}), a horizontal line is drawn from the 50% mortality point to intersect the graph, the point to intersection is extrapolated on the abscissa by dropping a vertical line on it and given the LC_{50} for the shrimps. The one way analysis of variance and the least significance difference test (LSD) were employed for analysis of data (Finney 1978).

III. Results

The 96h median Lethal concentration (LC_{50}) of the drilling fluids (water-base and oil-base) on the test organism marine water shrimp (Mysidoposis bahia) and brackish water shrimp (Palaemonetes africanus) were presented in fig. 1. The results showed that the oil-based muds were more toxic to the test organisms than the water-based muds. The 96 h LC_{50} of oil base drilling fluid were 9097.57 and 24130ppm greater than water base 28000 and 47260ppm to Mysidoposis bahia and Palaemonetes africanus respectively.

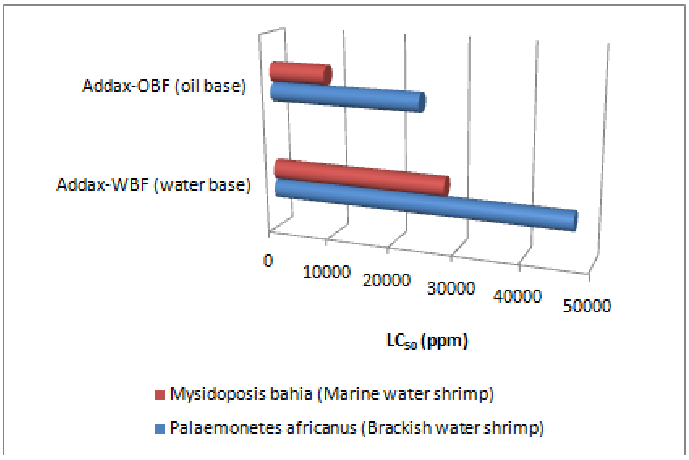

Fig. 1: The 96h LC_{50} (ppm) of drilling fluids marine and brackish water shrimps

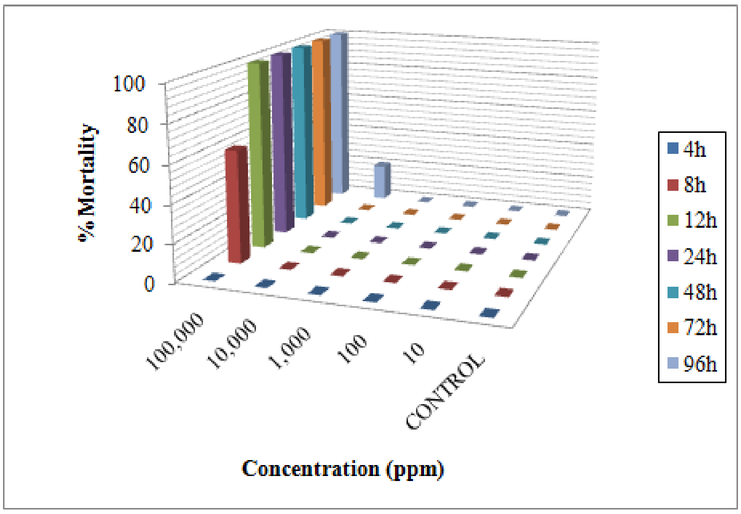

Fig. 2: Percentage (%) mortality of marine water shrimp Mysidoposis bahia to drilling fluid – Addax-WBF (Water base)

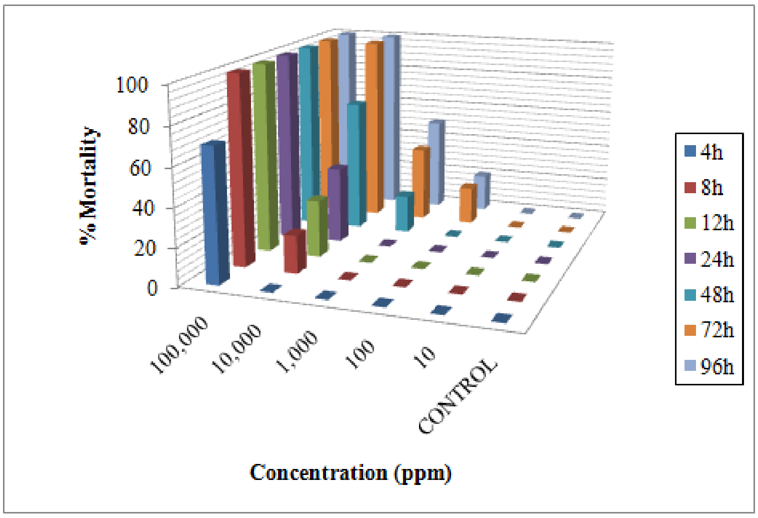

Fig. 3: Percentage (%) mortality of marine water shrimp Mysidoposis bahia to drilling fluid – Addax-OBF (Oil base)

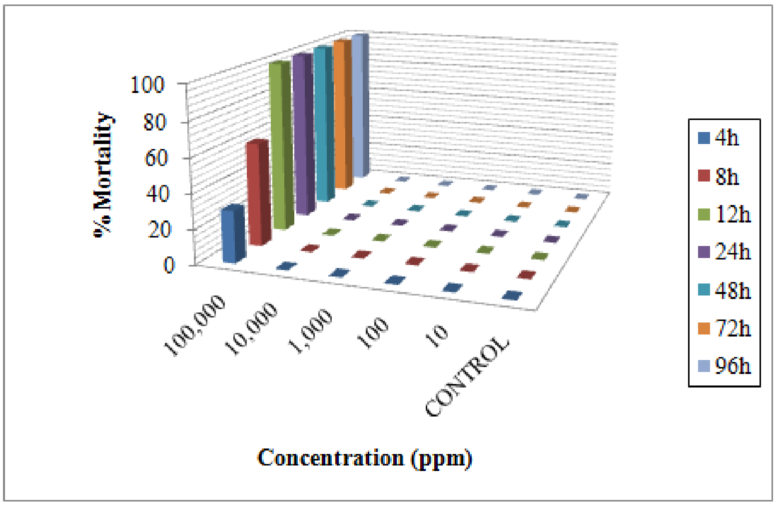

Fig.4: Percentage (%) mortality of brackish water crustacean Palaemonetes africanus to drilling fluid – Addax-WBF (Water base)

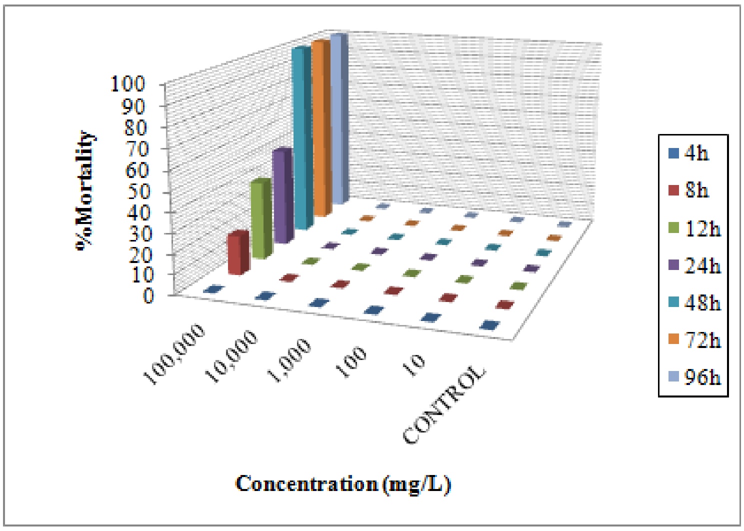

Fig. 5: Percentage (%) mortality of brackish water crustacean Palaemonetes africanus to drilling fluid – Addax-OBF (Oil base)

The percentage survival and mortality of the test organisms Mysidoposis bahia - marine water shrimp and Palaemonetes africanus – Brackish water juvenile shrimps, taken during toxicity of Drilling fluid - oil base and water base in marine and brackish water were shown in Table 2-5.

The value of some physical and chemical properties of the marine and brackish aquatic environments used for the study was presented in table 1. The general appearance of the water were clear, odour have objectionable sensory evaluation, colour decreases 1.00 and 10.00 Hazan, pH 8.21 and 7.96, Electrical conductivity (EC) 9200 and 7380µS/cm. Turbidity (2.0 and <1.0 NTU), Total hardness 3456.00 and 1920mg/L, Total alkalinity (142.95 and 220mg/L), Chloride (3488.0 and1568.6mg/L), Total Dissolved Solids (7400.0 and 6960.0mg/L), Total Solids (7435.0 and 7004.5mg/L), Total Suspended Solids (44.5 and 35.1mg/L), Nitrate (1.90 and 1.65mg/L), Sulphate (998.50 and 2.50mg/L), Calcium (1152.00 and 384.0mg/L), Magnesium (140.5 and 234.0mg/L). Biochemical Oxygen Demand (BOD) (9.10 and 27.9mg/L, Chemical Oxygen Demand (COD) (48.1 and 66.9mg/L), Total Iron (Fe) (0.81 and 0.21mg/L), Lead (Pb) (<0.001 and 0.07mg/L) and Copper (Cu) (0.02 and <0.001).

Table 1: Physical and chemical characteristics of marine and brackish water.

S/N	Physico-chemical characteristics	Unit	Marine water	Brackish water
1	General Appearance	-	Clear	Clear
2	Odour	-	Objectionable	Objectionable
3	Colour	Hazen	1.00	10.00
4	pH	-	8.21	7.96
5	Electrical Conductivity (EC)	µS/cm	9200.00	7380.00
6	Turbidity	NTU	<1.00	2.00
7	Total Hardness	mg/L	3456.00	1920.00
8	Total Alkalinity	mg/L	142.95	80.55
9	Chloride	mg/L	3488.00	1568.55
10	Total Suspended Solids (TSS)	mg/L	35.10	44.50
11	Total Dissolved Solids (TDS)	mg/L	7400.00	6960.00
12	Total Solids	mg/L	7435.00	7004.50
13	Nitrate	mg/L	1.90	1.65
14	Sulphate	mg/L	998.50	2.50
15	Calcium	mg/L	1152.00	384.00
16	Magnesium	mg/L	140.50	234.20
17	Biochemical Oxygen Demand (BOD)	mg/L	9.10	27.90
18	Chemical Oxygen Demand (COD)	mg/L	48.1	66.90
19	Total Iron (Fe)	mg/L	0.81	0.21
20	Lead (Pb)	mg/L	<0.001	0.07
21	Copper (Cu)	mg/L	0.02	<0.001

IV. Discussion

The results in fig.1 showed that the oil- based drilling fluid was more toxic to the test organisms, marine water shrimp (Mysidoposis bahia) and brackish water shrimp (Palaemonetes africanus) than the water-based drilling fluid. The 96h LC_{50} of the drilling fluids were Addax-OBF oil base in marine water (9098ppm) > Addax-OBF oil base in brackish water (24130ppm) > Addax-WBF water base in marine water (28000ppm) > Addax-WBF water base brackish water (47260ppm). Comparatively, marine water shrimp (Mysidoposis bahia) is more susceptible than brackish water shrimp (Palaemonetes africanus) to both water- and oil-base drilling fluids.

The low LC_{50} values of oil -based muds may be related to their chemical composition (Odokuma and Okpokwasili 1992). The presence of mineral oil in their liquid phase may be responsible for their increased toxicity. Sydnes (1985) and Strongren et al., (1988) have reported that water-based muds remain non- toxic even at very high concentrations (10,000ppm). This result revealed that toxicity of oil-based muds, may also contribute to persistence of these muds in environments in addition to the reduced biodegradability. However, It is interesting that not all the species, even physiologically similar group of micro-organisms, are similarly influenced by the presence of a given toxic chemical in their environment. The nature of interaction between effluents (toxicity set up) and microorganisms is complex due to various reactions taking place during a prolonged or previous exposure (Obire and Nrior, 2014). Oil base drilling fluid in marine water alone is toxic to the tested species at concentrations that are significantly greater than the levels of pollutant commonly detected in the environment (Hernondo et al., 2002). In this research, we limitation between 100 to 10000 which showed water base had low toxicity on marine water shrimp (Mysidoposis bahia) and brackish water shrimp (Palaemonetes africanus) did not have significant effects on the organism's mortality. These shrimps have perfect resistance against pollution of drilling fluids and the results indicated that Mysidoposis bahia and Palaemonetes africanus could be used for toxicity tracing drilling fluid in marine and brackish water. Therefore, drilling fluids and concentration of pollution in certain times of the year may cause mortality for a species of animals and does not have any effect on the others (Piri and Falahi, 1998). In general there was no significant difference between the sensitivity of any of the above bacteria and the higher organism used for the test as indicated by t-test used for analysis (Appendices 26-33) the difference in response of these bacterium and higher organisms from the three different sites could be due to difference in genetic make up (Patrick et al., 1991), prolonged or previous exposure to the effluent (Obire and Nrior, 2014), mutation (Zelibor et al., 1982) and relative utilization of the effluent for metabolism.

V. Conclusion

This study revealed that Addax-OBF oil-based fluids were more toxic to marine water shrimp (Mysidoposis bahia) and brackish water shrimp (Palaemonetes africanus) than Addax-WBF water-based drilling fluids. The 96hLC$_{50}$ of the water-based fluids to Mysidoposis bahia and Palaemonetes africanus respectively were all greater than 10,000 mg/L indicating that these water based muds were non toxic. All test organisms displayed similar levels of sensitivities to the two drilling fluids at 95% probability levels. Thus in the brackish water environment of the Niger Delta were a lot of exploration and production activities in the petroleum sector are concentrated the use of water-based drilling fluids should be encouraged because of their environmentally friendly (ease of biodegradation and non toxic) properties. Moreover, since these shrimps have perfect resistance against pollution of drilling fluids up to 10,000ppm, this research results indicated that Mysidoposis bahia and Palaemonetes africanus could be used for toxicity tracing drilling fluid in marine and brackish water.

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