The Effects of Spent Synthetic Based-Mud on Terrestrial and Aquatic Lives

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Amorin, R., Broni-Bediako, E. and Sasu, P. (2020), "The Effects of Spent Synthetic Based-Mud on Terrestrial and Aquatic Lives", *Proceedings of 6th UMaT Biennial International Mining and Mineral Conference,* Tarkwa, Accra, Ghana, pp. 58-63.

Abstract

Synthetic Based Muds (SBMs) are the major based fluid used in drilling operations due to the increasing desire to reduce environmental impact of offshore drilling operations associated with conventional oil-based fluids. However, drilling waste generated from the use of synthetic based fluids may still be harmful to the environment if discharged without adequate treatment. Their effects on the environment depend on their toxicity level (Polycyclic Aromatic Hydrocarbon (PAHs)) which may affect terrestrial and aquatic lives. This study was conducted to evaluate the effects of spent hydrocarbon SBMs on the environment using catfish fingerlings, maize grains, cowpea seeds and earthworms as test cases. The catfish fingerlings were exposed to water contaminated with different concentrations of SBMs to determine its lethal effects for 96 hours. Cowpea, maize grains and earthworms were also exposed to soils contaminated with different concentrations of SBMs for 21 days and 96 hours respectively. The concentrations used were 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45% and 50% mass/mass or vol/vol. The results revealed that higher concentrations of 30% to 50% of the SBMs were 50% and more lethal on the fingerlings. Also, soils containing traces of 5% and more of SBMs were unable to support good plant growth. Earthworms were unable to survive in soils contaminated with 10% and more of the SBMs. Untreated hydrocarbon synthetic based fluids are therefore harmful to both aquatic and terrestrial lives and should therefore be very well treated before disposal.

Keywords: Toxicity, Synthetic Based Mud, Contamination, Terrestrial, Aquatic

1 Introduction

Conventional Oil-based fluids have received many applications in hostile environments due to their superior performance over other drilling fluids. However, they have are associated with major environmental issues due to their non-biodegradability, toxicity (containing Polycyclic Aromatic Hydrocarbon (PAHs)), (Amorin *et al*., 2015; Dosunmu and Ogunrinde, 2010; Fadairo, *et al*., 2012), There have been some efforts to improve upon these oil based mud by developing the Synthetic-Based Muds (SBMs). These new oils are produced from synthetic hydrocarbon (olefins), ether, acetal and esters (Neff *et al*., 2000). Though, SBMs are more environmentally friendly to conventional OBMs, they could still be harmful to the environment if discharged without adequate treatment. Their effect on the environment depends on their toxicity levels. Piles of oil-based cuttings can affect local ecosystem in three ways. These include smothering organisms, direct toxic effect, and anoxic conditions caused by microbial degradation of the organic components in the waste (Gaurina-Medimurec *et al*., 2006). These toxic chemicals enter biological systems, disturb biochemical processes and alter normal organism functions (Enuneku and Ayobahan, 2014). Again, additives added to SBMs may also pose the same handling and disposal challenges as the base fluid (Strachan, 2010). The environmental effects resulting from the continues discharge of SBMs may be similar to those associated with OBM (Neff *et al*., 2000). This paper therefore evaluates the effect of spent (waste) drilling fluid on terrestrial and aquatic lives upon disposal.

2 Resources and Methods Used

The effects of spent synthetic hydrocarbon drilling mud on terrestrial and aquatic environments were investigated. For the terrestrial impact, maize and cowpea grains and earthworms were exposed to various concentrations of the spent SBM and their impact investigated. Also, aquatic impact was investigated by exposing catfish fingerlings to various concentrations of the spent SBMs and their effects on the fingerlings were analysed. The aim of the aquatic experiment was to determine the concentration of the SBMs that would be lethal to 50% of the fingerlings (LC50).

2.1 Investigation the Effect of SBMs on Terrestrial Life

Maize and Cowpea grains were planted in loam soil which had been contaminated with different concentrations of spent SBM (Table 1). Some few holes were created under the seedling-bags for partial leaching. Two maize and cowpea seeds each were sowed into separate seedling bag and periodically watered to keep the soil relatively moist. The growth and development of the maize and cowpea were monitored for 21 days.

Two earthworms (Lumbricina) each were also placed in soil contaminated with various concentrations of spent SBMs (Table 2). The effects of the toxicity of the SBMs on the earthworms were evaluated. They were monitored for 96 hours.

Table 1 Concentrations of Spent SBMs and Soil Samples Used in Sowing Maize and Cowpea Grains

Sample	Soil (g)	SBMs (g)
Control	500	0
Bag 1	475	25
Bag 2	450	50
Bag 3	425	75
Bag 4	400	100
Bag 5	375	125
Bag 6	350	150
Bag 7	325	175
Bag 8	300	200
Bag 9	275	225
Bag 10	250	250

Table 2 Concentrations of Spent SBMs Used to Contaminate Soil

Sample	Soil (g)	SBMs (g)
Control	50	0
Bag 1	50	5
Bag 2	50	10
Bag 3	50	15
Bag 4	50	20
Bag 5	50	25
Bag 6	50	30
Bag 7	50	35
Bag 8	50	40
Bag 9	50	45
Bag 10	50	50

2.2 Investigation the Effect of SBMs on Aquatic Life

Ten catfish fingerlings (Clarias gariepinus) were exposed to different concentrations of SBMs to determine the LC50. The effects of the toxicity of the SBMs on the test species were analysed and recorded within 96 hours. Mortality of the fingerlings were recorded at the end of 24, 48, 72 and 96 hours respectively. The fingerlings were placed in containers containing the fingerlings' native-pond water. The fingerlings were allowed to acclimatise to their new environment for about 24 hours before the start of the experiment. Different concentrations of the SBMs in grams (g): 0 g, 50 g, 100 g, 150 g, 200 g, 250 g, 300 g, 350 g, 400 g, 450 g and 500 g respectively were mixed with 1 000 ml water and allowed to settle (Table 3.).

Table 3 Concentrations of Spent SBMs in Pond Water Containing the Fingerlings

Sample	Pond Water (g)	SBMs (g)	SBMs (%)
Control	1000	0	0
Bag 1	1000	50	5
Bag 2	1000	100	10
Bag 3	1000	150	15
Bag 4	1000	200	20
Bag 5	1000	250	25
Bag 6	1000	300	30
Bag 7	1000	350	35
Bag 8	1000	400	40
Bag 9	1000	450	45
Bag 10	1000	500	50

3 Results and Discussion

3.1 Terrestrial Toxicity Test

It was observed that the introduction of the SBM into the soil affected the percentage germination of the maize and cowpea grains, the height of the developed plants, the colour and number of leaves. The magnitude of the impact increased with increasing concentration of SBM introduced.

Maize and Cowpea Grains Germination

The maize and cowpea grains germinated within 3 to 5 days for contaminations of 0% to 5%. The rest failed to germinate (Table 4). It was observed that the germination and development of the seeds were significantly affected by the increasing measure of SBM contamination to the soil. The control group for maize and cowpea plant grew quite well since no SBM concentration was added to the soil. The 5% contamination showed a partial support for the maize and cowpea growth (Figs. 1 and 2).

Table 4 Effect of Spent SBM Concentrations on Maize and Cowpea Seeds Germination

Sample	SBMs (%)	Germination (%)	
		Maize	Cowpea
Control	0	100	100
Bag 1	5	100	100
Bag 2	10	0	0

Bag 3	15	0	0
Bag 4	20	0	0
Bag 5	25	0	0
Bag 6	30	0	0
Bag 7	35	0	0
Bag 8	40	0	0
Bag 9	45	0	0
Bag 10	50	0	0

Fig. 1 (A) Cowpea in Control Experiment; (B) Cowpea in 5 % Contaminated Soil

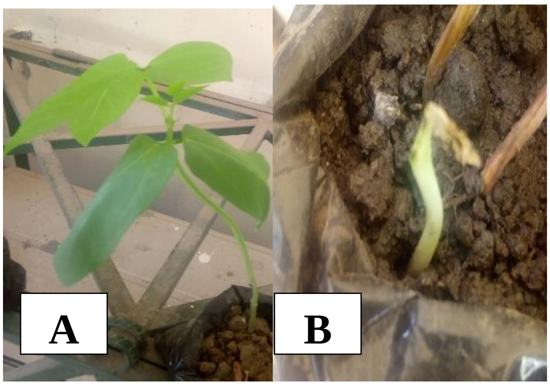

Fig. 2 (A) Growth of Cowpea in Control Experiment; (B) Growth of Cowpea in 5% SBF Contaminated Soil

Both maize grains and cowpea seeds sown in soils contaminated with 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, and 50% of the spent SBMs failed to germinate (Fig. 3). These soils may have become too toxic and contaminated that they could not support plant growth. Careful observations revealed that the grains sown were still whole (not rotten) but oily. This may have contributed to lack of good aeration to support plant growth.

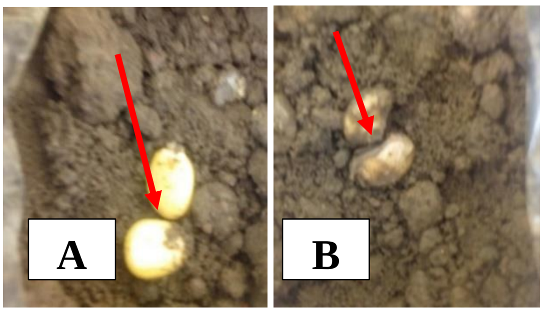

Fig. 3 Failed Maize (A) and Cowpea (B) Seeds

Plant Height

The heights of the plants were monitored every two days. The total plant height after the 21 days revealed that the presence of SBM in the soil affected the height of the plants. After the 21 days of monitoring, the maize and cowpea seeds in the control experiment grew and developed well as compared to the sample with 5% contamination. The cowpea seeds in the soil with 5% contamination grew to only 4 cm while that of the control grew to 25.5 cm. The cowpea and maize plants recorded close to 75% (4.0 cm) and 15% (19.8 cm) decrease in growth compared to their controls respectively (Table 5). Jidere *et al.* (2012), reported a decrease in maize and cowpea crops in the first year of cultivation in a field contaminated with hydrocarbons. Abayomi and Adeniyi (2005) also reported that unfavourable soil conditions are detrimental to seed germination in cowpea than maize. This may be the reason for the cowpea recording a lower plant growth in this study. The decrease in the plant growth can therefore be attributed to the toxicity of the SBM.

Table 5 Total Heights of Maize and Cowpea Plants after 21 Days

Plant	Control	5%
Maize Height (cm)	26.6	19.8
Cowpea Height (cm)	25.5	4.0

Leaf Count and Colour

The average number of leaves for the maize was 5 leaves while that of the cowpea was 6 leaves in the control experiment. The average number of leaves for maize in the soil contaminated with 5% of the SBMs, was 4 leaves while that of the cowpea was not able to grow leaves. The 5% contamination show detrimental effect on the cowpea plant and the partial leave withered with time.

Generally, the leaves of the maize and cowpea plants in the control experiment were green on all sides from the time of germination. The leaves of the maize plant in the 5% contaminated soil turned yellow at the ends of the 21 days and withered thereafter (Figs. 2 and 5). This may be attributed to deficiency of nitrogen in the soil as reported by Matimelo *et al*. (2020). Also, the presence of of metals in drilling fluids may range from macroelements (Ca, Mg, K, Na), microelements (Cu, Co, Fe, Mn, Zn, As, Al, Ba), and heavy metals (Cr, Cd, Pb, Ni, Hg) with Ca, K and Mg concentrations sometimes are in the majority (Mikos-Szymańska *et al*., 2018), the base oil used for the formulation of the SBM and the possible lack of aeration due to the constituent of the SBM (Neff *et al*., 2000) may have contributed to the poor growth of the plants.

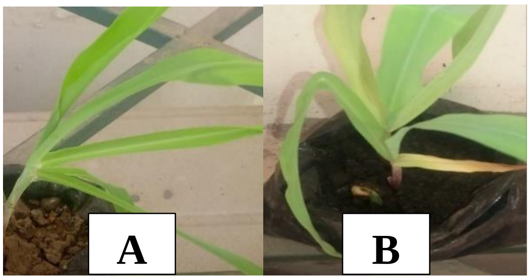

Fig. 5 (A) Leaf Colour of Maize Plant in Control Soil; (B) Leaf Colour of Maize Plant in 5% SBFs Contaminated Soil

Earthworm Toxicity Testing

Figure 6 presents the results of the effect of SBM concentration on the earthworms after the 96 hours exposure. The higher the concentrations of SBMs exposure, the higher its impact on the earthworm. The earthworms placed in the soil contaminated with the highest (50%) SBMs concentration died first after 0.17 hours (10.2 minutes). The earthworms which were placed in the control and those in the 5% contaminated soil survived the 96 hours experiment. It took 3.5 hours for the earthworms exposed to the 10% contaminated soil to die. An earlier work by Hanna and Weaver (2002) revealed that a soil contaminated with oil content of 0.5% was not harmful to survival of earthworms for 7 days but an oil concentration of 1.5% reduced survival to less than 40%.

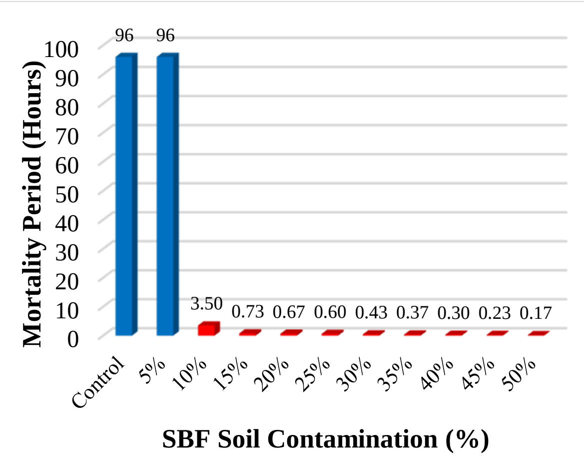

Fig. 6 Mortality of Earthworms Exposed to Soil Contaminated with Different Concentrations of SBMs for 96 hours

3.2 Acute Aquatic Toxicity Test

The introduction of the spent SBMs into the various waters made the water very cloudy, muddy and oily therefore increasing the turbidity of the water (reducing oxygen content of the water). After the fingerlings were introduced to different concentrations of the SBMs for 96 hours, the following observations were made:

i. The mortality of the fingerlings increased with increase in SBM contamination beyond concentrations of 10%;
ii. 15%, 20% and 25% SBM were lethal but less than the LC50 (50% mortality) of the fingerlings; and
iii. SBMs contamination of 30%, 35%, were all lethal to 50% while 40%, 45% and 50% were lethal to more than 50% of the fingerlings (Table 6).

Table 6 Mortality Test on Catfish Fingerlings Exposed to Spent SBMs

Sample	SBMs (%)	Mortality of Fingerlings (%)				
		24 hrs	48 hrs	72 hrs	96 hrs	Total %
Control	0	0	0	0	0	0
Bag 1	5	0	0	0	0	0
Bag 2	10	0	0	0	0	0
Bag 3	15	0	0	10	0	10
Bag 4	20	0	0	0	20	20
Bag 5	25	0	0	0	40	40
Bag 6	30	0	10	20	20	50
Bag 7	35	0	0	30	20	50
Bag 8	40	0	0	40	30	70
Bag 9	45	0	0	40	40	80
Bag 10	50	0	0	0	100	100

It can be reported that the higher the percentage contamination, the higher the toxicity and the higher the percentage mortality. There should therefore be conscious effort to ensure that water bodies are not contaminated with untreated spent SBMs to avoid mortalities aquatic organisms. A similar work by Gbadebo *et al.* (2009) revealed that fingerlings of Clarias garipinus survived 2% of crude oil and spent oil concentrations for 96 hours while concentrations of 4-10% resulted in a 100% mortality rate.

4 Conclusions and Recommendations

From the experiment conducted, it can be concluded that untreated spent hydrocarbon synthetic mud systems are harmful to the environment. This is because they contain toxic substances which do not support live. This is because:

i. SBM contamination at 5% concentration is unable to support good plant growth;
ii. SBM contamination above 5% concentration is 100% lethal to soil living organisms like earthworms.
iii. SBM contamination above 15% is lethal to 50% and above on catfish fingerlings which are relatively stronger than tilapia fingerlings. Thus, concentrations above 15% failed the LC50 mortality test

It is recommended that:

i. Untreated synthetic hydrocarbon-based fluids should be handled with care to avoid any spillages into the environment.

ii. Untreated synthetic based fluids should be very well treated before disposal.
iii. There should be more research and enforcement into the use of more environmentally friendly base fluids like the ester synthetic based fluids which is more biodegradable.

Acknowledgements

The authors appreciate the support received from the department of Petroleum Engineering, UMaT, Tarkwa and Zeal Environmental Technology Limited, Takoradi.

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