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Effect of Reversible Invert Emulsion Fluid Additives on The Environment – An Environmental Concern During Drilling Operation

[I]Okoro Emeka Emmanuel, [II]Dosunmu Adewale, [III]Oriji Boniface
[I]World Bank African Centre of Excellence in Oil Field Chemical, University of Port Harcourt
[II]Shell Aret Adams Chair in Petroleum Engineering, University of Port Harcourt
[III]Dept. of Petroleum Engineering, University of Port Harcourt

Abstract
The effect of reversible invert emulsion drilling fluid additives on the soil has been examined in order to evaluate their toxicity and possible environmental impacts that may result from their indiscriminate disposal. Development of effective policies for discharges depends on consideration of the specific local environmental conditions that govern the fate of discharge materials, the scientific basis for assessing the potential for effects in that environment, and balanced consideration of the environmental effects and relative costs of discharge versus other disposal options. This paper reviews the framework that will help achieve general regulatory acceptance of the discharge of reversible invert emulsion mud. In this study, the contaminated soil samples were collected and analysed for metals (iron, copper, zinc, lead, nickel, chromium, manganese, calcium and magnesium) using Atomic Absorption Spectrophotometry (AAS) method. The results showed that Calcium (Ca) has the highest concentration followed by Iron (Fe), Copper (Cu) with varying level of toxic metals like lead (Pb), Nickel (Ni), Manganese (Mn) and Chromium (Cr) in the soil sample. Metals like Fe, Mn and Cu generally have values higher than that of the United States Environmental Protection Agency and World Health Organization Standards thereby implying possible negative impacts on the immediate environments. It is therefore recommended that wastes resulting from oil cuttings and drilling muds should be properly treated before it is disposed into the environment by oil exploration companies.

Keywords
Reversible Invert Emulsion Mud, Metals, Toxicity, Framework for Comparative Assessment and handling

I. Introduction

During the drilling operation of oil and gas, drilling fluid, cuttings and other waste materials generated in the process must be properly disposed. The Reversible Invert Emulsion mud which consists of diverse chemical components is used in the drilling operation in order to achieve specific purpose at a given site. Considerable concern has been expressed in recent years about the effect of drilling fluids and its constituents on the environment [1]. Most additives (example, barite) are practically inert toxicologically, although in some cases they may cause physical damage to organisms.

Exploration and Production (E&P) wastes are introduced into the environment through accidental spills, leaks, blowouts and drilling operations. These wastes toxic chemicals pose significant risks to the environment, human health as well as wildlife. The potential for accidental or routine release of drilling wastes into the environment is alarming and thus threaten to sustain the industry operations. Many of the toxic chemicals associated with oil and gas drilling are known to accumulate and magnify in the food chain posing a risk to aquatic organisms higher in the food chain, such as fish and birds.

Awareness of the environment among the public, regulatory agencies, customers and service companies has made environmental concerns a key factor in drilling operations. Environmental issues are broad-based and complex, influencing all aspects of drilling fluid system design and use. Health, Safety and Environmental (HS&E) regulations overlap to some degree, but they consider the issues from different perspectives.

Health and safety issues deal primarily with worker protection, while environmental issues deal with any impact to the environment and/or the health of the community exposed to the effects of drilling operations. Preventing pollution and minimizing environmental impact in a cost-effective way are the foremost tasks confronting the industry today. It has been established that a discharge of bentonite and barite dumped on the ground, will prevent plant growth until other natural processes develop a new topsoil, but are not themselves toxic [1].

1. Minimizing Pollution

The first step in minimizing pollution is to identify pollution sources associated with drilling fluids at the well site. Discharges into the water are usually grouped into three categories:

I. **Point source:** A source of pollution that is discharged into the environment through a distinct point. An example of a point source for water might be cuttings discharged through a pipe into the ocean.
II. **Non-point source:** A source of pollution not discharged into the environment through a distinct point. An example of a non-point source for water might be rainwater that runs off a property in sheet flow (not through a ditch or channel).
III. **Mobile sources:** A point source of pollution that is not stationary. An example for water might be a bilge pump on a boat.

Discharges of solid waste are made into or upon the land and are not classified as any of the above three sources.

The second step in minimizing pollution is identifying materials that may have a negative impact on the environment. The level of impact a discharge makes on the environment is a function of what types of materials are contained in the waste and the environment into which they are discharged. For example, high levels of sodium chloride in drilling fluids will have little impact if discharged into the ocean which has naturally high levels of salt. Discharge of the same drilling fluid into a freshwater stream or farm land would have a much greater impact because the animal and plant life are not acclimated to salt water environments.

II. Background of the Study

Early in the development of drilling fluids, it is found that crude oil and diesel oil produce muds that were excellent for inhibiting water-sensitive shales and clays extended to reach wells, as well as high-density mud and drilling through salts [2]. However, environmental consideration resulted in drilling with these muds being phased out and led to the development of a new invert mud system, which are called synthetic-based drilling fluids (SBDFs). These new system meet difficulties drilling targets with reduce environmental impact, so SBDFs were developed as environmentally friendly and have technological advantages over WBDFs and oil-based drilling fluids [3].

The reversible invert emulsion systems are simple and easy to run. The additives used in these fluid systems are common additives used in oil based muds. The invert emulsion systems are formulated as an emulsion in which the oil forms the continuous phase and brine water serves as dispersed phase. The pre-treatment of emulsion muds before its disposal is considered to be easier and less costly than Oil based muds (OBM). Oils can be removed from the cuttings with the help of mechanical cuttings dryers and thermal desorption units.

The physical and chemical properties of OBM'S that provide excellent performance in the wellbore can lead to environmental concerns in some receiving environments. When conventional OBM cuttings are discharged, the OBM prevents water from entering into the cuttings and allowing them to disperse into the water column. While this minimizes impacts to the water column, it sometimes leads to high organic loading conditions on the seafloor around the location. In some receiving environments, cuttings piles can form in the immediate vicinity of the discharge [4]. Ether-based muds were originally planned to be marginally cheaper than the cost of OBMs combined with the cost of destroying the cuttings on land.

III. Materials and Methods

The API recommended standardized methods for laboratory, recommended practice: standard procedure for field testing water-based and oil-based drilling fluids (Drilling Fluids, API 13 B) was followed in the mud formulation. An oil water ratio of 70:30 was used to formulate the mud system (Tables 1). The mud was formulated using Basic Mud Engineering Programme IE Mud Calculator version 1.1 by Okoro Emeka and Dosunmu Adewale.

A. Mud Formulation and Performance

The materials and chemical additives were obtained from EL Serve Services.

Table 1: Reversible Invert Emulsion Mud Formulation for 70:30 Oil-Water Ratio

S/N	Additives	Quantity And Unit
1	Polytriethanolamine Base	195ml
2	Oil	78.2ml
3	Water Volume	80g
4	$CaCl_2$	12g
5	Primary Emulsifier	8ml
6	Secondary Emulsifier	8g
7	Organophilic Clay	120g
8	Barite	11g
9	Lime	10g
10	Caustic Soda	3g

The addition of each additive in their proper sequence during mixing of the mud optimizes the performance of each system. The order of addition as listed below is the most common procedure for preparation of oil base muds, though each mud system may require some modification of this procedure. Organophilic viscosifiers require considerable quantity of shear to fully develop their viscosity.

The procedure for mixing the mud systems are as follow:

1. Addition of the required quantity of base oil to the mixing vessel;
2. Addition of Organophilic Clay as required;
3. Addition of the primary emulsifier and secondary emulsifier as required;
4. Addition of lime as required;
5. Addition of brine;
6. Addition of filtration control additives when required;
7. Mixing of the above for several minutes to ensure a good emulsion was formed; and
8. Addition of weighting material as required for the desired density was added.

The drilling fluid will be subjected to shear rates and their corresponding shear stresses obtained using the Fann rheometer.

B. Handling Reversible Invert Emulsion Drilling Fluid

When working with drilling fluids, four routes of exposure are observed: dermal, inhalation, oral and other. Dermal (skin) exposure to drilling fluids is reported to cause skin irritation and contact dermatitis. IPIECA (2009) reported that skin irritation can be associated with C8-C14 paraffins, which do not penetrate the skin, but are absorbed into the skin, causing irritation. Besides, calcium chloride which is used as the discontinuous phase (brine), was classified as an eye irritant. Awareness on the hazardous materials, potential exposures and their health effects are critical. The use of personal protective equipment (PPE) is recommended to minimize the direct contact to drilling fluid. PPEs may include chemical splash goggles, gloves, rubber boots and coveralls. Wearing chemical resistant gloves and laboratory clothing is the primary method used to prevent skin exposure to hazardous chemicals. When working with drilling fluids, if ventilation is not adequate it is recommended that goggles and self-contained respirators are worn at all times.

C. Framework for Comparative Assessment

The comparative risk assessment compares potential human health and environmental impacts of allowing the discharge of Synthesis Base Mud cuttings to the potential impacts of not allowing their discharge. This assessment can be framed in terms of risk reduction to human health and the environment and pollution prevention.

A framework for a comparative risk assessment for the discharge of reversible invert emulsion drilling fluids will be developed. The framework will help identify potential impacts and benefits associated with the use of reversible invert emulsion drilling muds.

Baseline Assumptions

1. Ether-based mud is so biodegradable and causes no serious environmental problems
2. The lack of aromatic compound in the polyether (Polytriethanolamine) enhances its environmental acceptability, as well as health and safety aspects
3. Reversible Invert mud system will replace both OBM and water base muds

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4. Deep and shallow water wells can only be drilled using Reversible Invert Emulsion mud
5. The reversible invert emulsion mud system do not use mineral oil for lubricity or to free stuck pipe
6. An average of 12% of mud volume is retained on the drill cuttings

D. Metal analysis

One g of each of the sample type was digested using mixture of perchloric acid, nitric acid and sulphuric acid in the ratio 1:2:2. The prepared solution was analysed for the elements / metals of interest using atomic absorption spectrometer (AAS). The results obtained were compared with both World Health Organization (WHO) guidelines and united state environmental protection agency (USEPA) standard for drilling waste disposal.

IV. Results and Discussion

Reversible Invert Emulsion based drilling fluids present a significant pollution prevention opportunity because the fluids are easily reversed from water-in-oil to oil-in-water emulsion, and smaller volumes of metals are discharged with the cuttings than for water–based muds.

Table 2 : Rheological Properties for the Reversible Invert Emulsion Mud at 120°F

S/n	Rheological Properties	Result
1	600	90
2	300	81
3	200	71
4	100	61
5	6	51
6	3	41
7	10 Sec. (lb/100 ft^2)	30
8	10 Min. (lb/100 ft^2)	10
9	ES (Volts)	804
10	PV (cP)	9
11	YP (lb/100 ft^2)	72
12	Alkalinity	1.7
13	Excess Lime	2.21

1. Framework

Reversible Invert Emulsion Muds are expected to replace Oil Base Muds (OBMs) in complicated and difficult drilling situations. Figure 1 shows the process assumed for drilling with reversible invert emulsion muds. Because of the initial cost, it is expected that the mud will be taken ashore and processed for reuse; only the drill cuttings will be treated and discharged.

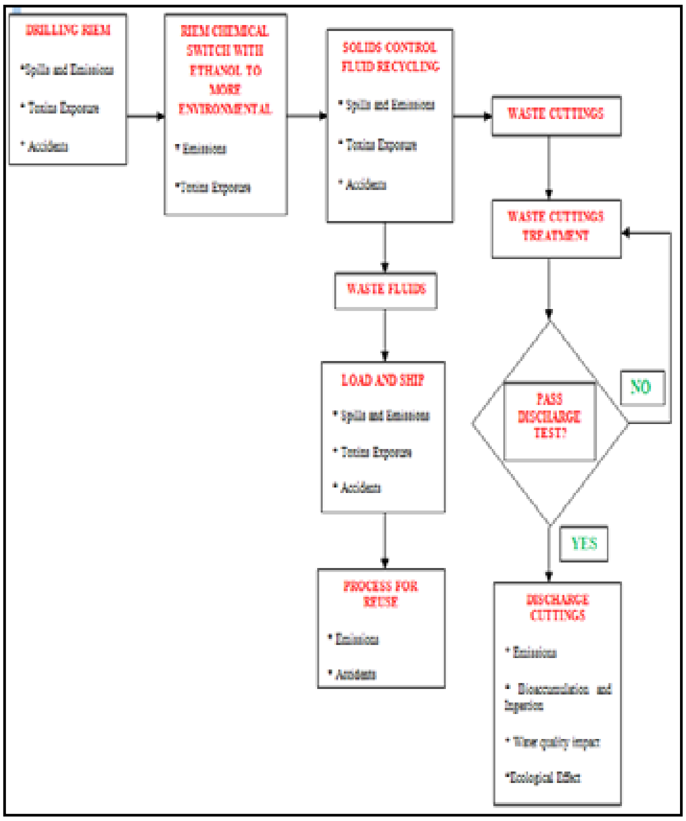

Fig. 1: Flow chart for handling Reversible Invert Emulsion Mud after Drilling Operation

2. Metal Analysis

Trace metals occur naturally in soils (but rarely at toxic levels), sedimentary deposits and water bodies; therefore, there are normal background concentrations of these metals. These metals also found their way (anthropogenic sources) into soils, vegetations, water bodies and sediments via airborne particulate matter in the form of dust and vehicular emission.

Metallic elements such as Fe, Zn, Mo, Cu, Co and Cr are known to be essential elements. They play vital roles in various metabolic activities in plants and animals at trace level, however, at high concentration, they may be potentially toxic [5]. Copper is an essential substance to life, it is a part of several enzymes including Tyrosinase which helps in formation of melanin pigment. It also helps in utilization of iron. Heavy metals such as Pb, Cd and Ni are toxic even at trace level and they adversely affect life under varying health conditions. The toxicity of heavy metals in aquatic environment is largely a function of water chemistry and sediment composition in the water body system.

The soil, plants and water in the neighbourhood where drilling mud cuttings are discharged are being threatened by pollution. Prevention is still the best method to protect the environment from contamination of heavy metal, more so, that cleaning of contaminated soil is difficult and expensive. This study therefore, investigated the concentration levels of potentially harmful toxic metals in reversible invert emulsion mud. Figure 2 will help in establishing the safety level of the environment and a data base for further studies.

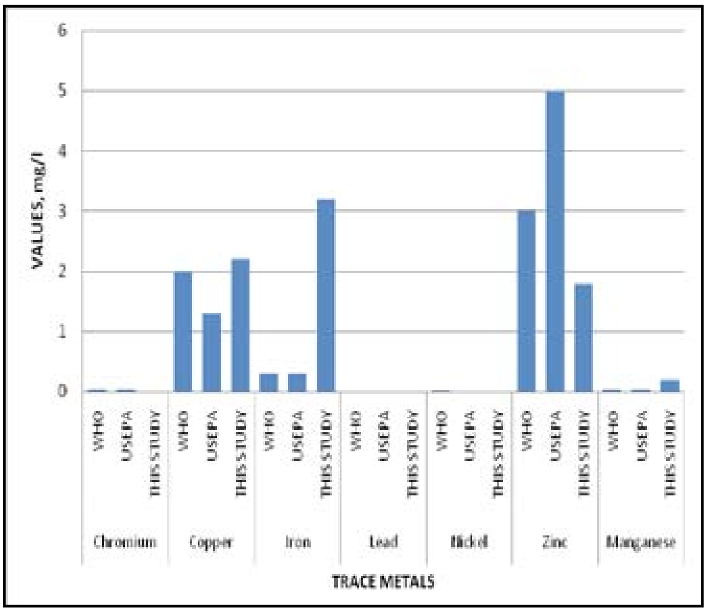

Fig. 2: Comparism of Trace Metals in this Study with Standards

The results also generally indicated that iron is relatively higher in concentration than all metals. These values were generally higher when compared with the established standard (WHO and USEPA). This then explains why there may be corrosion in the drilling equipments and oil water waste storage facility and even abundant of iron in the soils of the study area.

The continuous entry of these metals into the surrounding environment can result in serious contamination. Reference [6] (1968) inferred that chromium has a high potential of accumulating in the soil. Where they are less mobile and less absorbed by plant the adverse effect is the high level of accumulation and contamination in soil. It has also been observed that both the oil-based and water-based drill wastes are relatively rich in calcium (in this study 240 mg/l), magnesium and potassium which are differently required by different categories of plants and animals in the environment. The environmental impacts of drilling muds and cuttings aspect of oil production activities can be extensive and biologically significant.

V. Conclusions

All the activities involved in the hydrocarbon exploration and production according to Reference [5] (2013) normally have one impact or the other on the environment. However, the greatest impact arises from the release of wastes into the environment in concentration that is not naturally found in such environment. This study has revealed the high concentrations of trace metals which are released into the environment during oil-exploitation and processing. These discharges have potential environmental implications.

It is therefore recommended that wastes resulting from oil activities (cuttings & muds) should be properly treated before it is disposed into the environment by oil exploration companies.

VI. Acknowledgements

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