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Comparative Analysis of Drilling Waste Disposal Method

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Abstract

Biodegradation, Stabilization, Incineration (Burning) and re-injection methods of handling drilling wastes were investigated and the central objective is a comparative analysis of drilling waste disposal methods, while the specific objective is to examine the various methods of managing drilling wastes and adapt the technique which is more effective and efficient.

The re-injection method is chosen based on the fact that it gives permanent 'elimination' of the waste (s) from the environment.The stabilization method causes great corrosion to the adjacent properties (materials). The biodegradation was not chosen because of the disadvantages such as the presence of resins and asphaltenes, which are resistant to biodegradation and sometimes the environmental conditions may not be favorable for the micro-organism to act on the waste material(s).The incineration method causes atmospheric pollution and has a very short life span. The pre-treatment of the waste, such as flocculation, should be carried out before adopting the re-injection method.

***Keywords*:** Re-injection method, Biodegradation, Drilling Waste, Flocculation, Fixation process, Associated Gas, Mist Droplets, Effluent limitation.Osmotic Effect.

1.0 Introduction

The petroleum industry generates wastes in the course of the exploration and production of petroleum.Some of these wastes include:

(a) **Gas:** Associated gases, exhaust gas, combustion gas.

(b) **Particulates:** Mist droplets of water or mud carried in the air stream, foam, liquid condensate and other film strengthening substances.

(c) **Water:** Fresh water, true and colloidal solutions, sodium and calcium salts; especially their chlorides, detergents, flocculants, cellulose, emulsion, and other suspensions.

d) **Oil:** Cuttings from the drilled formations, which contain oil, bentonite, clay barites, diesel or crude and other filtration control agents.

Some of the waste treatment and disposal practices in the exploration and production operations such as offshore disposal, Landfill, burning, and biodegradation are not meeting the existing effluent limitations set by the Nigerian government. However, drilling wastes are expected to undergo further treatment in order to meet the more stringent regulations that are currently being developed worldwide.

The Federal effluent limitations establishing the best practicable control technology (BPT) currently available have been promulgated for the onshore and offshore sub-categories of the oil producing industry. In establishing the limitations, The Department of Petroleum Resources (DPR) and the Federal Ministry of Environment (formerly Federal Environmental Protection Agency (FEPA), which are charged with enforcement, took into account information on age and size of facility, raw materials, manufacturing process, produced products, treatment technology available, energy requirement and costs.

To meet these stringent regulations, most offshore oil platform treat the produced waste by flocculation before dumping into the sea while for onshore locations, fixation process is more common.The central objective of this study is the comparative analysis of drilling waste disposal methods, while the specific objectives are:To examine the various methods of managing drilling wastes and adopt the technique which is more effective and efficient. As well as verifying the impact of drilling waste on the environment.

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Drilling fluids are chemical mixtures used for drilling in the extraction of oil and gas from the earth's crust,[1]. Essentially, drilling fluid is a suspension of solid (for example, clays, bentonite, barite, small cutting etc.) in liquids (i.e. water or oil or in liquid emulsions) with additives as required to modify its properties, [2]. Drilling fluids therefore encompass all the compositions used to aid the production and removal of cutting from boreholes. Adam et al[3] Emphasised that drilling fluid isused in the rotary drilling process to exert sufficient hydrostatic pressure against subsurface formation to prevent formation fluids flowing into the well, as well as keeping the newly drilled borehole open until steel casing can be cemented in the hole.

Basically, there are two types of drilling fluid systems, viz: water-based mud (W. B.M) and oil-based mud (O.B.M.). There is an intermediate type called the synthetic mud or pseudo- oil-based mud, [4]. The type and composition of the drilling mud depends upon the requirement of the particular drilling operation(s). Harrison [5] stated that "the choice of drilling fluid depends on several factors, of which the most important include economies, rate of contamination, available make-up water, pressures and down-hole temperature".

2.0 Mud Raw Material Compositions

The mud slurry to be used for any drilling location must meet certain properties consistent with the geology of the location. Such properties, which are usually determined and specified, include, the mud weight, the lithology (i.e. plastic, viscosity, yield point, gel strength, and the funnel viscosity); the filtrate (quantity and quality); and others, such as lubricity, corrosivity and osmotic effects, [6].

3.0 Drilling Mud as a Waste

Drilling mud, drilling formation cutting, cement, spent chemicals from well completion / work- over,acidization, routine household solid and liquid wastes, are some of the discharges from drilling rig platform

Drilling mud containing several manufacture chemical additives may end up either as waste materials with the cuttings or as spent mud at the end of the drilling operations [7].

The Flow of Mud Filtrate through a Mudcake

$$dv_f/dt = KA\frac{\Delta\rho}{\mu h_{mc}} \qquad (1)$$

dV_f/dt = the filtration rate, (cm^3/s),
K = the permeability of the mudcake(darcies),
A = the area of the filtrate paper(cm^2),
$\Delta\rho = the\ Pressure\ drop\ across\ the\ the\ mudcake\ (atm),$
$\mu = the\ viscosity\ of\ the\ mud\ filtrate\ (cp), and$
h_{mc} = the thickness of the filter (mud) cake(cm).

At any time, t, during the filtration process, the volume of the solids in the mud that has been filtered is equal to the volume of solids deposited in the filter cake:

$f_{sm}v_m = f_{sc}h_{mc}A,$

Where f_{sm} is the volume fraction of solids in the mud and f_{sc} is the volume of solids in the cake, or $f_{sm}(h_{mc}A + V_f)$ = $f_{sc}h_{mc}A$.

Therefore,

$$h_{mc} = \frac{f_{sm}\,v_f}{A(f_{sc} - f_{sm})} = \frac{v_f}{A\left(\frac{f_{sc}}{f_{sm}} - 1\right)} \qquad (2)$$

Inserting this expression for $h_{mc} into\ Eqn. (1) and\ integrating,$ we get

$$\int_0^{vf} v_f dv_f = \int_0^t \frac{kA\Delta\rho}{\mu} A\left(\frac{f_{sc}}{f_{sm}} - 1\right) dt,$$

$$\frac{v_f^2}{2} = \frac{k}{\mu}A^2\left(\frac{f_{sc}}{f_{sm}} - 1\right)\Delta\rho t,$$

Or

$$v_f = \sqrt{2k\Delta\rho} - \left(\frac{f_{sc}}{f_{sm}} - 1\right)\frac{A\sqrt{t}}{\sqrt{\mu}}. \qquad (3)$$

Eqn. (3) indicates that the filtrate volume is proportional to the square root of the time period used [3].

4.0 Water-Based Mud

Swacco [8] observed that for a particular drilling fluid (water or oil) a wide range of mud mixtures could be derived to present various mud characteristics that can meet the requirements of any drilling location. However, a major problem in the development and treatment of drilling mud is the lack of general consensus on the requirement for a drilling location, [9]. In many cases, there are difficulties in equating obtained surface measurement with down-hole performance.

Jansen and Wind [10] observed that for water based mud, the percentage of water mixed with the mud is much more than the mud composition. He further explained that Water—Based Mud generally have no firm legislative restrictions other than the chemical discharge limits imposed by the Department of Petroleum Resources. It is however recognized that Water-Based Mud contains toxic element, such as colloidal solutions, flocculants, cuttings, emulsion and cellulosic.

Table:1 The Advantages And Disadvantages Of Water-Based Mud (WBM)

S/N	ADVANTAGES	DISADVANTAGES
1	Provides the highest probability of drilling holes in area(s) of known instability including the minimization of: (i) Shale hydration and associated problems i.e. stuck pipe, out-of-gauge hole etc., (ii) Repeated washing and reaming to keep the hole open, (iii) Abnormal viscosity and solids accumulation due to dispersion of clays.	In areas of formation instability, water-based Mud may not be very effective. This is due to its emulsive characteristics (i.e. it does not stick easily).
2	Addition of electrolytes to the mud results in dehydration of water-wet shale cuttings. This dehydration gives firm undispersed cuttings that reach the surface as particles large enough to be removed effectively by the shale shaker.	Shows weak lubricity in directional drilling.
3	Less damaging to the permeability of producing oil formation.	
4	Easy to formulate and less expensive.	
5	Does not require stringent disposal conditions as the oil-based mud.	
6	Does not require special laundry facilities for the personnel.	

Source: Dawes[11]

5.0 Oil-Based Mud

Oil-based mud is not legalized in Nigeria. But in other countries, such as United Kingdom, the environmental governing body, the Health and Safety Executive (HSE) have legislated a 1% O.O.C. discharge limit on all oil-based mud cuttings, effective from 1994, [8]. A 10% O.O.C. exemption has however been granted for all development well planned prior to 1991. This has enabled a number of major operators to continue with oil-based mud for the time being. Effective from 1997, all oil-based mud well shall be required to comply with the 1% O.O.C. discharge limit and currently there is a field-proven cleaning process which can achieve this legislative limit,[12].

Table 2The Advantages And Disadvantages Of Oil-Based Mud (OBM)

S/N	Advantages	Disadvantages
1	Good rheological properties at very high temperatures.	High initial cost.
2	More inhibitive than inhibitive water based mud	Requires more stringent pollution control procedures.
3	Effective against all types of corrosion	Remedial treatment for lost circulation.
4	Superior lubricating characteristics	Reduces effectiveness of some logging tools.

Source: Adam et al [3]

6.0 Data Presentation

When drilling wastes have undergone primary and secondary treatment processes, it is finally disposed of by any suitable means such as the ones discussed below.

Stabilization

This method is applicable strictly to oil-based mud. This is achieved by binding the waste material with an inorganic substance such as quicklime (Calcium Oxide). This forms an inert product, which does not allow the fluid to leach out. The stabilized material can be disposed of under less stringent conditions than unstabilized drilling mud and can now be used for land reclamation and road construction; where there is not a requirement for high load-bearing properties. When the stabilized solids have been used as road building materials, salt may find its way or leached into nearby ditches, causing plant stress and water pollution. The technique is also risky to handle as a great deal of corrosive dust arises from the process. Although, quicklime appears so far to be the best binding agent, other materials might also be applicable such as cement and pulverized fuel, ash waste from coal-fired power stations.

Burning

The direct burning of contaminated drilling fluids is not recommended except in very remote areas, since it usually causes atmospheric pollution when fluid is burnt in the open. It also tends to spread and be absorbed into the ground. In addition, a tarry residue may remain since it is rarely possible to achieve complete combustion. These problems can be overcome by using an incinerator. The type of incinerator best suited for handling drilling wastes is the rotary kiln. In this system, air is supplied tangentially from a suitable compressor or fan blower to support combustion. The rotation of the kiln tumbles the waste to provide extensive contact with the hot burner gases. The gases produced from the rotary kiln passes through an oxidizer, wet scrubber, and bag house before being vented to the atmosphere. Also, the ash from the burnt waste passes through an ash cooler before being collected on a temporary ash storage bin. Depending on the material used for construction, the lifetime of the unit may be quite short but should be capable of dealing with at least 100-600 tones of the waste. It is important to point out that the direct burning of drilling waste may result in salt being transformed into organic compounds, which increases the acidity of the soil.

Biodegradation

Fluids and oily wastes can sometimes be broken down using biological processes. Biodegrading of fluids by microorganisms can only take place at an oil-water interface, so that on land the oil must be mixed with a moist substrate. The rate of degradation depends upon temperature and availability of oxygen and appropriate nutrients, containing nitrogen and phosphorous. Some chemical components such as resins and asphaltenes are resistant to degradation and even after prolonged periods, up to 20% of the original materials may be left unaffected.

A more effective approach is to distribute the fluids and cuttings on land set aside for the purpose; a technique sometimes referred to as land farming. It may take as long as three years before the bulk of the waste is broken down, although degradation rates can often be increased by regular aeration of the soil and by the addition of fertilizers, such as urea and ammonium phosphate. The method is only likely to be applicable to relatively small fluids because of the amount of land required (0.25 hectares for 100 tones of the waste). Though, this method is mostly applicable to oil-based mud, the method is also not suitable in cold climate region. The contaminated material should not contain more than about 2O% oil and ideally the land selected should be of low value, located well away from portable source water supply and should exhibit low permeability. The topsoil should first be loosened by means of a harrow and the area bounded to contain any fluid run-off. The waste is then spread over the surface to a depth of not more than 20cm, the maximum application rate being about 400 tones of the waste per hectare of land. The waste should be left to weather until it is no longer sticky before being thoroughly mixed in with the soil using a plough. Mixing should be repeated at intervals of 4-6 weeks for the first six months but less frequently, thereafter.

This biodegradation technique is applicable to all locations of drilling. For offshore and swamp locations, the waste is transported to a designated site for the operation.

Re-Injection

Re-injection, the dumping of the filtrate in a depleted (non-active) reservoir while the residue is further treated for economic value has been proposed as a more permanent solution to the disposal of drilling wastes because the method has the ability to limit the possibility of groundwater contamination, as well as the ability to dispose of other waste that would have been taken to shore for disposal. This method is applicable to both water and oil-based mud. The system for re-injection is as shown in Figure 2.8. A suitable non-active reservoir around the area of operation is chosen. At the completion of the drilling, the drilling wastes are passed through the various treatment processes before being finally emptied into the reservoir after proper consideration of the following factors:

i. The permeability of the reservoir
ii. The porosity of the chosen reservoir, etc.

Since drilling fluids contains considerable dissolved ions in its liquid phase, contamination of fresh water aquifer may occur. To avoid this, the study of the reservoir characterization is inevitable in utilizing re-injection as a drilling waste disposal option.

7.0 Discussion

The development of drilling wastes management involves the economic evaluation of alternatives, and the selection of the most effective and satisfactory system. The least expensive alternative ordinarily is expected to be accepted (chosen), but the effectiveness and the benefit of the system may condemn its acceptability. Thus, understanding the economic, operational and environmental limitations of the available wastes disposal methods is an important step toward selecting the best option for a particular area. A framework of vital parameters such as resource used, air emissions, transportation and safety concerns are employed in evaluating the best available option. Table 4.1 is a summary of findings from the various waste disposal methods study in this research.

Table 3: Findings From The Various Wastes Disposal Methods

Methods	Benefits	Limitations
STABILIZATION	-The product can be used for land reclamation and road construction. - The stabilized material can be disposed of under less stringent conditions than unstabilized mud. - The method is applicable to all locations. - The process provides for further re-treatment of the waste.	- Strictly for oil-based mud -The technique is risky to handle as it gives rise to a great deal of corrosive dust which may spread to adjacent properties - When stabilized solids have been used as road materials, salt may have been leached into nearby ditches, causing plant stress and water pollution.
BURNING	- Complete combustion when incinerator is used, which reduces the waste to the barest minimum. - The time required for incineration is very short. - It involves a simple technology.	- It causes atmospheric pollutions. - At high temperature, salt can be transformed into organic acid compounds, which increases the acidity of the soil. - Safety concerns dealings with high temperatures on locations - A tarry residue may remain - High initial cost of equipment, as the process requires several pieces of air pollution control equipments.
BIODEGRADATIO N	- Mostly recommended for oil and oily based waste - mostly applicable to oil-based mud in shore lines - waste treatment is inexpensive relative to other technologies - simple process with little equipment needed - well accepted practice in many areas	- It takes a longer time for the process to be completed (60 days to 3years). -Up to 20% of the original materials may be left unaffected. -Runoff water in areas of high rainfall can cause surface water contamination. -Shallow water table in Some areas allow ground water impact. - Only applicable to small-scale operations. -Not suitable in cold climates region as low temperatures slows down the degradation process.
RE-INJECTION	-For both water and oil-based mud - zero (permanent) discharge of the waste from the environment if the system is properly designed. - limits the possibility of surface and ground water contaminations. - Ability to dispose of other waste such as rainwater and oily stop tank waters that would have been taken to shore for disposals.	-The most significant limitation of injection method is the requirement for a suitable injection formation i.e. the availability of an appropriate injection zone - Mistakes in application can lead to expensive cleanup cost. - Extensive equipment and labour requirements. - Accidental discharge into the underground water can pollutes it.

Conclusion

The various methods of disposal of drilling waste in accordance with established legal framework in Nigeria have been analysed in this study.

Based on the analyses of the economic, operational and environmental limitations, as well as the factors affecting the selection of different methods, the re-injection method is chosen as the best option because it gives a permanent containment of both oil-based and water-based mud. In summary, the method is technically feasible, commercially viable, and managerially sound.

Biodegradation is the degradation of the waste using biological processes. The presence of resins and asphaltenes in materials to be biodegraded makes this method unattractive for certain types of drilling wastes, and sometimes the environmental condition(s) may not be favourable. The incineration method deals with the burning of the waste materials. This technique is only applicable in remote areas because it causes atmospheric pollution.

Stabilization method involves the binding of the waste material with an inorganic substance, such as quicklime. This method gives rise to great deal of corrosive dust, which may spread to adjacent area.

The pre-treatment of the waste, such as flocculation, should be carried out before adopting the re-injection method.

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