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Research Article

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Economic Analysis of Oilfield Waste Management Systems in the Niger Delta (A Case Study)

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Abstract The Petroleum industry is mostly confronted with problems related to oilfield waste disposal generated from drilling and production of oil and gas wells. This study was carried out to examine the challenges in the methods of oilfield waste management in the Niger Delta region. This study gives a comparative economic evaluation of oilfield waste treatment method for decision making. Selecting the best treatment method for production operations will bring about maximum benefit and good return on investment. Sampling techniques were used in selecting 45 oil companies (drilling and Production) for the study by the use of questionnaires. 40 Properly filled questionnaires were sorted and the contents were analysed using descriptive statistics of tables, percentages and bar graphs. Different oilfield waste treatment and handling methods were assessed and evaluated on the basis of operational, environmental and economic point of view. Net Present Value (NPV). The result shows high level of negative environmental impact of oilfield waste management as a result of not improving on the methods already adopted and lack of enforcement in the regulation, exploration and production activities of the petroleum industry. Hence, this study recommends continuous modifications and improvement on methods adopted and enforcing the existing laws guiding the regulation of the industry activities.

Keywords Waste Management, oilfield, Net Present Value, Disposal, Economic Analysis.

Introduction

The petroleum industry plays a major role in the world supply of energy in the form of natural gas and crude oil. These hydrocarbon fossil fuels are used for both domestic and industrial needs. The upstream sector of the petroleum industry which conducts all exploration and production (E&P) activities exploit these natural resources and generate significant volumes of wastes in the process. Environmental regulatory agencies have defined field waste as waste generated from the production and exploration activities of the petroleum industry [1]. Several methods have been employed in managing these wastes depending on environmental regulatory guidelines. In offshore fields, the options are limited to discharge, underground injections and transport back to shore for disposal. Onshore operators have a wider range of options - some wastes are managed onsite while others are removed to offsite commercial waste disposal facilities. Most onshore waste management options employed include land spreading and land farming, evaporation and burial site, underground injection, incineration and other thermal treatment, bioremediation and composting, reuse, reduction and recycling [2]. The well drilling process, generates two major types of wastes - used drilling fluids and drill cuttings. Drilling fluids (or mud) are used to support the drilling process. Mud are circulated through the drill bit to lubricate the bit, cool the drill string and to aid in transporting the drill cuttings to the surface, where the mud and cuttings are separated by mechanical means. These wastes when discharged can have significant impact to the environment. The first step in proactive waste management is to understand what wastes are generated and how they impact the environment [3]. These impacts can be eliminated or minimized through proper implementation of effective waste management system. This system includes not only the treatment and disposal of waste; they also include minimizing and reducing the amount and /or toxicity of wastes being generated).

Oilfield Drilling Waste

Waste generated from drilling operations include drilling fluids (mud) and solids, cement returns to surface, salt water, oil, and drill formation cuttings [4]. The volume of the waste generated will depend on the well architecture, type of mud system used and other operating factors.

i. Drill Cuttings: These consist of inert rock fragments, and other solid materials produced from geological formations in the drill hole and include cured cement carried to the top with the mud.
ii. Drill Fluid or Mud

The major functions drilling mud include:

- Hydrostatic pressure in the well to prevent formation fluids from entering the well.
- Transport cuttings out of hole.
- Lubricate drill string.
- Cool and clean the drill bit.
- Stabilize the well bore.

Materials and Method

Assessment and evaluation of various waste treatment and handling methods. Evaluation of drilling waste management methods using the weighted decision matrix method .and Economic Evaluation of the various waste Management options was carried out.

A sample population of forty-five (45) waste remediation companies were selected for the survey study. Three states in the Niger delta region were selected for the study, namely Rivers, Bayelsa and Delta State. Questionnaires were used to obtain information from the respondents. The filled questionnaires were retrieved and used for analysis. Collated data were sorted, and the content analysed using statistical tools (Tables, Frequency Distribution and Percentages) and bar graph to ascertain the challenges in the methods of oilfield waste management and services.

Various waste treatment and handling methods were assessed and evaluated based on environmental, operational and economic considerations. The choice of treatment of the waste differ, depending on whether the operation was onshore or offshore.

Decision regarding the choices were made on the basis of the followingconditions:

- The nature of cuttings (oil base mud, water base mud, sand, clay, etc.)
- The nature of the cuttings
- The environment specificity of the disposal site (sensitivity, natural resources etc.), available logistics, local possibilities (onshore), as well as associated costs.

Treatment Methods

The various treatment methods in existence in the industry are briefly discussed as follows:

Thermal Methods

Thermal methods are waste management technologies, which use high temperatures to destroy hydrocarbon contaminated waste e.g. oil-based cuttings. For destroying organics, thermal treatment is the most efficient method and it reduces the volume of inorganics such as metals and salts [5]. Thermal treatment can be a temporarily process to reduce toxic waste and volume and prepare a waste stream for further disposal or it can be a final treatment resulting in inert solids, water and recovered based fluid. Thermal treatment technology is generally a land-based installation (onshore). Thermal treatment method can be grouped into incineration and thermal desorption**.**

Incineration

Incineration is typically used to destroy organic wastes that are highly toxic, highly inflammable and resistant to biological degradation or pose high level of risk to human health and environment. It combust wastes at high temperatures (typically 1200 °C to 150 °C) and converted to less bulky non-hazardous materials or less hazardous prior to incineration [6]. The advantages of incineration includes volume reduction, complete destruction and possible resource recovery, cost for incinerating waste with high water contents can be high due to high energy required to vaporize the water. The types of kiln used for incinerating waste are the rotary kilns and cement kilns. Cement kilnsare less cheap alternative method to a rotary kiln. In cement kilns, oil-based mud drilling wastes is used in a fuel-blending program as a substitute for fuel that would otherwise be needed to fire the kiln. Cement kiln temperatures (about 1400 °C to 150 °C) and residence times are sufficient to achieve thermal destruction of organics in the waste stream. The ash resulting from oilfield waste combustion is incorporated into the cement grains or pores, providing aluminium, silica, clay, and other minerals typically added in the cement raw material feed stream.

Thermal Desorption

Thermal desorption uses non-oxidizing process to vaporize volatiles and semi-volatile oils through the application of heat. Depending on operating temperatures, thermal desorption processes are categorized into low-temperature desorption and high-temperature desorption systems respectively. Low-temperature thermal desorption system typically operates at 250 °C to 350 °C which may be sufficient to treat wastes with light hydrocarbons, aromatics (e.g. Toluene, xylenes ethyl benzene and benzene,) and other organics that are volatile. Systems with a high-temperature mostly operate at a temperature up to 520 °C and can produce a low final oil contents for waste with heavy compounds such as aromatics [7].

Biological Method

Biological treatment of waste (also known as Bio-treatment or bioremediation) employs the use of micro-organisms (bacteria, worms and fungi) to biologically degrade hydrocarbon-contaminated waste into non-toxic residues. The major objective is to accelerate the natural decomposition process of the hydrocarbon contaminant by controlling oxygen supply, temperature, and moisture, conducive for the microorganisms to survive. Depending on the volume or size of the hydrocarbon components, the bioremediation environment and the type of treatment method utilized, bioremediation may be a slow process and might require months or years to achieve the desire results. The types of bioremediation process include:

Composting

This involves mixing the waste stream with bulky agents such as wood chippings, straw, rice husks to increase the porosity and aeration potentials to aid biodegradation. The function of the bulky agent is to provide adequate porosity to allow aeration even when moisture levels are high. The addition of nitrogen and phosphorus based fertilizers respectively can also enhance microbial activity and reduce the time required to achieve the desired level of biodegradation. To optimize biodegradation moisture conditions, the compost mixture is maintained about 40% to 60% water by weight. Increased mixture temperatures (30°C to 70°C) increase microbial metabolic rate.

Bioreactors

This is similar to composting but the reactions occur in an open, closed vessel or impoundment. The environmental additives that are used for bioreactors are agricultural waste, after treatment liquids may be transported to wastewater treatment facilities, injected or discharged. The solid that is produced may be buried as well as used as landfills. However, capital expenditure (CAPEX) and operating costs (OPEX) for bioreactors are higher than other forms of bioremediation.

Vermiculture

In this method, worms are used to decompose organic waste into a material that has the capability of supplying nutrients to help sustain plant growth. For several years, worms have been used to convert organic waste into organic fertilizer. As of recent, this process has been tested and found successful in treating certain synthetic-based drilling wastes. Worm cast (manure) has important fertilizer properties. The process may provide an alternative drill cutting disposal method.

Land Application

This method allows the soil's naturally occurring microbial population to change, and assimilate waste constituents in place. In general, land farming refers to the continuous application of waste to the soil surface whereas land spreading and land treatment are often used interchangeably to describe the one-time application of waste to the soil surface.

Land Farming

Land farming is the continuous application of waste to the soil surface, using the original soil microorganisms to naturally biodegrade hydrocarbon constituents, change and assimilates waste constituents. This is a cheaper oilfield waste management approach. It does not have effect on soils and may improve the water-retaining capacity of certain sandy soils thus reducing the fertilizer losses.

Land Treatment (Land Spreading)

Land spreading can be determined by calculating loading rate which considers the hydrocarbon concentration, absolute salt concentration, metal concentration and pH level after mixing with the soil. The waste is spread on the land and integrated into the upper soil (about 6" to 8" of soil) to improve hydrocarbon volatilization and biodegradation. The process is optimized just like land farming. However, implementation considerations differ, because land spreading receives a single dose application of waste, the accumulation potential of waste components in the soil is reduced.

Phytoremediation

Phytoremediation is a remediation technology that has been successful for the remediation of green cuttings contaminated with heavy metal compounds and some volatile organic compounds. It involves the use of plants to aid or assist the degradation or extraction of hydrocarbon contaminants from drill cuttings.

Chemical Method (Solidification, Stabilization and Encapsulation)

These methods are employed when the drill cuttings are treated with plenty of mud that may not be suitable for the next disposal step. The contaminants i.e. oil may leach from the waste which makes them not suitable for land application. The processes required for drill cuttings stabilization and solidification are as follows:

Solidification

This is a technology that encapsulates the waste into a monolithic mass of solid with high structural integrity; the encapsulation may be of a large mass of solid. The process is basically a mechanical interaction between the waste and solidifying agent, which results in a monolithic solid mass.Stabilization/Solidification applicability may depend on the nature of additives added.

Onsite Disposal Method

Burial is the most common onshore waste disposal technique. It involves the placement of waste in natural or artificial excavations such as pits or landfills. Generally the waste is buried in the same reserve pit used for temporal storage of the spent mud and cuttings after the liquid is allowed to evaporate. Onsite burial is a relatively low-cost method that requires waste to be transported away from the drill site. Thus this is very attractive to most operators [8].

Pits and Landfill

This involves the use of earthen or lined pits in managing the waste for onshore operations. The cuttings are separated by the shale shakers which are sent to the reserve pits, that also gathers storm water from the rig. Whereas using landfills, the wastes are placed in the underground. The waste is covered with clean soil or any material that is inert at the close of each day or cycle. One major thing to be considered in operating a landfill site is to ensure long-term containment

Slurry Injection

Injection involves injecting waste in slurry form into underground formations where they are permanently disposed. Drill cuttings are processed into smaller particles that are mixed with water or some other liquid to make the slurry. The slurry produced is injected into an underground formation at pressures high enough to crack the formation. Continuous injection typically creates a large fracture from the point of injection while intermittent injection creates a series of planes that are vertical which form a zone of fracture within the injection point. However, care should be taken to avoid deep fractures that might interfere with drinking water aquifers.

Regulation Requirements for oilfield waste management

Oilfield waste materials are toxic to humans and the ecosystems and are specifically regulated by governmental authority. In the absence of governmental regulations, guidelines issued by relevant international or regional organizations are usually used. Therefore, direct discharge of untreated oilfield drilling mud are not allowed in most part of the world. The oil companies operating in the Niger Delta region of Nigeria are expected to adhere to world best practices as prescribed by the Department of Petroleum Resources (DPR), which is the regulator of the Nigerian Petroleum Industry in the country. The DPR have emphasized the implementation of the guidelines and standards by the oil operators.

Economic Evaluation of Drilling Waste Management Methods

The NPV method of evaluating the desirability of investments is mathematically represented by the following equation:

$$NPV = \frac{OPEX}{(1+i_d)^n} - CAPEX \qquad (1)$$

Where: CAPEX = Capital Expenditure, e.g. Cost of Equipment

OPEX = Operating Expenditure, e.g. Cost of Labour, Cost of Transportation, Cost of Energy, etc.

i_d = The discount rate.

n = Equipment projects economic life in years.

NPV = Net Present Value

Assumptions

The following are the assumptions made in this study:

1. The equipment have a five-year service life;
2. There is no tax implication to the investment;
3. There is no salvage value;
4. Base case of 11% discount factor is considered.
5. Land is available.

An Excel in-built function was used for the calculation of the NPV for a period of five years. The Net Present Values were evaluated.

Results and Discussion

The economic analysis of various oilfield waste management methods was carried out and the options were evaluated .The results are presented in Table 1- 5.

Table 1: NPV Analysis Disposal Method

Years	Injection Method		Land fills		Pits	
	CAPEX ($)	OPEX ($)	CAPEX ($)	OPEX ($)	CAPEX ($)	OPEX ($)
0	125,000	0	0	0	0	0
1	0	25,000	0	45,000	0	35,000
2	0	25,000	0	45,000	0	35,000
3	0	25,000	0	45,000	0	35,000
4	0	25,000	0	45,000	0	35,000
5	0	25,000	0	45,000	0	35,000
NPV	**217,397**		**166,315**		**129,356**	

Table 2: NPV Analysis for Thermal Method

	Thermal Desorption		Incineration	
Years	CAPEX ($)	OPEX ($)	CAPEX (&)	OPEX ($)
0	-900,000	0	-1,000,000	0
1	0	270,639	0	300,000
2	0	270,639	0	300,000
3	0	270,639	0	300,000
4	0	270,639	0	300,000
5	0	270,639	0	300,000
NPV	**100,254**		**108,769**	

Table 3: NPV Analysis for Biological Method

	Composting		Bioreactors		Vermiculture		Land Spreading		Land Farming		Phyto-remediation	
Years	CAPEX ($)	OPEX ($)	CAPEX (&)	OPEX (&)	CAPEX ($)	OPEX ($)	CAPEX ($)	OPEX ($)	CAPEX ($)	OPEX ($)	CAPEX ($)	OPEX ($)
0	0	0	-170,000	0	0	0	0	0	0	0	0	0
1	0	50,000	0	130,000	0	80,000	0	75,000	0	50,000	0	40,000
2	0	50,000	0	130,000	0	80,000	0	75,000	0	50,000	0	40,000
3	0	50,000	0	130,000	0	80,000	0	75,000	0	50,000	0	40,000
4	0	50,000	0	130,000	0	80,000	0	75,000	0	50,000	0	40,000
5	0	50,000	0	130,000	0	80,000	0	75,000	0	50,000	0	40,000
NPV	**184,795**		**310,467**		**268,172**		**277,192**		**184,795**		**134,086**	

Table 4: NPV Analysis for Chemical Method

Years	Chemical Method	
	CAPEX ($)	OPEX ($)
0	-500,000	0
1	0	250,000
2	0	250,000
3	0	250,000
4	0	250,000
5	0	250,000
NPV	**447,697**	

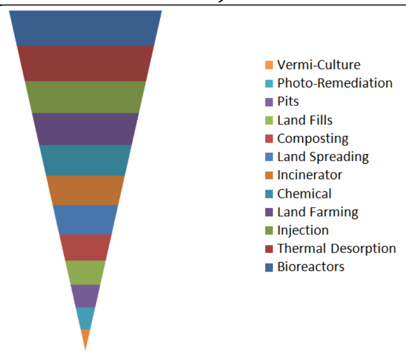

Figure 1: A Plot of the Comparative Analyses of the Waste Management Method

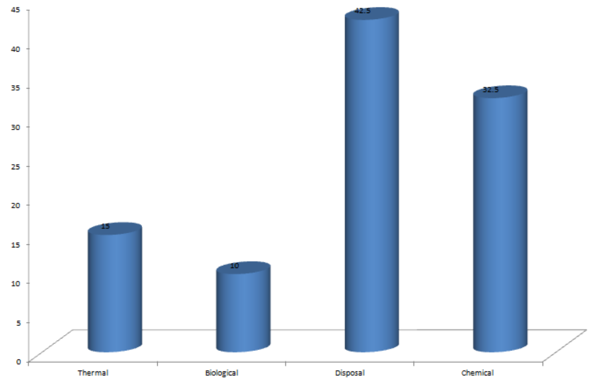

Figure 2: Showing the most challenging treatment Method inoil field Waste Management

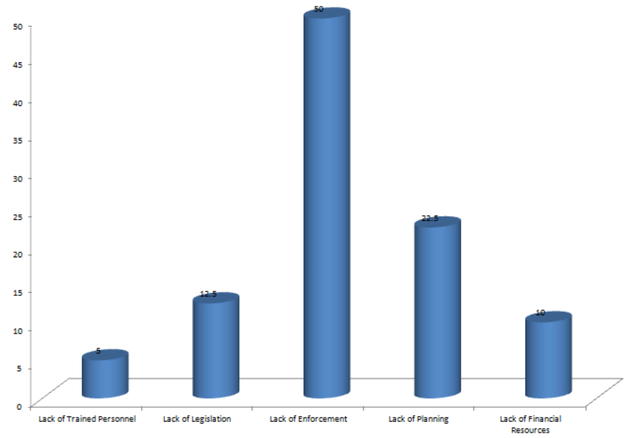

Figure 3: Influence of various factors on Oilfield Waste Management Services.

Discussion

The choice of any oilfield waste treatment option is a combination of its cost-effectiveness and minimal to zero environmental impact. The economic cost, which is the cost incurred in executing a selected method. This includes all associated costs such as capital costs (CAPEX) operating costs (OPEX) and energy costs etc. the results showed that the Bioreactor method was more expensive when compared to other bioremediation method, but it is more technologically advanced and less environmental impact (**Table 3**). Pits and landfill methods are relatively low-cost method and it does not need waste to be transported away from the drill site. The disadvantages of this is that it may not be a good choice for oilfield waste streams that contain high concentrations of oil, salts and other harmful ground water contaminants. The NPV analysis (**Table 2- 4**) indicated that the thermal desorption method (with the lowest positive value) is the most cost effective and technologically advanced comparatively. Disposal method (42.5%) Chemical method (32.5%). Biological methods, reflecting 10% as the Thermal Desorption methods are not easily destroyed in the process, rather 15% challenges are inherent in this method (**figure 4**). Furthermore, A total of (50%) of respondents agreed that one major challenge in oilfield waste management services is lack of strict enforcement and compliance to the environmental principles and guidelines lack of planning, in which (22.5%) of respondents agreed that lack of planning **(figure 3)**

Thus, in spite of very good legislation in place, the results in the works showed that lack of enforcement on the part of the government regulators was the major factor that resulted in poor oilfield waste management in the region.

Conclusion

The economic analysis of different methods for managing oilfield waste in the energy industry was evaluated. However, it is imperative that an ecological risk assessment at field locations be carried out to ascertain the oilfield waste management technology required. This will reduce the environmental impact arising from poor waste management and disposal by the exploration and production of oil and Gas in the Niger Delta. The results showed that an effective economic analysis of waste management method would contribute to corporate profit in terms of reducing operating costs and potential liability cost that could have been incurred from environmental pollution.

Recommendations

Based on the work, the following recommendations were made for oilfield waste management efficiency.

1. The Department of Petroleum Resources (DPR) and the Federal Ministry of Environment should work on improving the regulation of waste management techniques through strict enforcement and compliance of their environmental guidelines and principles
2. There should be continuous modification and improvement of the relevant regulations to meet the increasing and challenging industry.
3. There is need to integrate waste data and ecological survey work in order to enable reliable ecological risk assessment.
4. The industry should apply waste management methods that can results in useful materials for drilling or minor road construction. By doing this, oil field wastes can be converted into profit making for the oil industry and the environment will not be contaminated.

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Appendix

QUESTIONNAIRE FOR OILFIELD WASTE MANAGEMENT SYSTEM IN NIGER DELTA

A. OILFIELD WASTE HANDLING: PLEASE TICK APPROPRIATE SPACES.

1. What are the available oilfield waste management systems currently in use?
   Thermal method □ Biological method □
   Disposal method □ Chemical method □
2. How are the waste been managed currently in Niger Delta?
   Reduction □ Recycle □ Disposal □
3. If Disposal , how often is the method used?
   6 months □ 1 year □ 2 years □ 4 years □
4. Which of the waste management method is most challenging to the environment?
   Thermal □ Biological □ Disposal □ Chemical □
5. Which of the waste management methods is most economical to use?
   Thermal □ Biological □Disposal □ Chemical □
6. Would you support the need to reduce the amount of biodegradable waste sent to land fill?
   Yes□ No□
7. Do you agree that the quantity of waste sent for disposal to land fill should be minimized?
   Yes □ No □
8. Do you support the transportation of oil field waste to landfill in the Niger Delta?

Yes□ No □

9. Do you think that after the cost effective capture of recyclable and compostable material, the recovery of energy from oilfield waste through a thermal process is a sustainable waste management policy?
   Yes □ No □
10. If your answer to question 9 is No, please tell us what type of treatment method you prefer ________________
11. Which is the largest volume of waste generated?

Produced water □ Drilling waste □Associate waste □ Industrial waste □

12. Which is the preferred thermal method?
    Thermal Desorption □ Incineration □
13. Which is the preferred biological method?
    Composting □ Bioreactors □ Vermiculture □
    Land spreading □ Land farming □ Phyto-remediation □
14. Which is the preferred Disposal method?
    Injection method □ Landfills □ Pits □
15. The type of waste generated mostly depends on:
    Well Architecture □ Type of mud system □
    Other operating factors □
16. Most effective way to reduce the volume of oilfield waste is:

Solid control □ Mud system monitoring □Slim holes□ Recycling□ Treatment Disposal □

B. PROBLEMS ENCOUNTERED IN OILFIELD WASTE MANAGEMENT SERVICES. Please tick appropriate spaces.

17. Lack of trained personnel.
    Very Serious □ Serious□ Not so Serious □ No Problem □
18. Lack of legislation.
    Very Serious □ Serious□ Not so Serious □ No Problem □
19. Lack of enforcement measure and capability.
    Very Serious □ Serious □ Not so Serious □ No Problem □
20. Lack of planning.
    Very Serious □ Serious □ Not so Serious □ No problem □
21. Difficulty in locating and acquiring land fill site.
    Very Serious □ Serious □ Not so Serious □ No Problem □
22. Poor cooperation by government Agencies.

Very Serious □ Serious □ Not so Serious □ No Problem □

23. Poor response to waste minimization (reuse/recycling).
    Very Serious □ Serious □ Not so Serious □ No Problem □
24. Lack of qualified private contractors.
    Very Serious □ Serious □ Not so Serious □ No Problem □
25. Difficult to control contractual service.
    Very Serious □ Serious □ Not so Serious □ No Problem □
26. Lack of control on hazardous waste.
    Very Serious □ Serious □ Not so Serious □ No Problem □
27. Lack of financial resources.
    Very Serious □ Serious □ Not so Serious □ No Problem □