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Estimation of Energy Content in Drilling Wastes of Hydrocarbon Industry in India with Possibility of Utilizing This Energy

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Oil and gas exploration activities have grown substantially in last few years and with higher energy demands would grow further. This process generates drilling wastes comprising of drilling fluid or mud associated with broken drill bits and grinds. A large quantity of waste is generated which is contaminated with oil and other chemicals. The present study is directed towards the estimation of energy content of this waste with possibility of utilizing this energy and simultaneously reducing the volume for safe and environment friendly disposal.

Key Words: Oil exploration waste, Drill mud, Energy content, Incineration, Energy utilization.

INTRODUCTION

To meet with the growing demand of energy and escalation of the price of petroleum and its products, more oil drilling and hydrocarbon exploration activities both offshore and onshore are going on. These drilling activities are associated with number of steps, beginning with surveys to locate reserves till the activity is complete[1]. During the process in each step solid wastes are generated. Though many methods are suggested for the disposal of these wastes, no regular practice of disposal have so far been available.

There have been several years of efforts to develop modern technology allowing modifications for various aspects of drilling. Through these efforts increase in oil and gas production with less drilling and less waste generation could be achieved. But this does not eliminate production of wastes. Generation of wastes depends upon the drilling fluid and the methodology adopted in drilling. A review article[2] on the state-of-art discusses elaborately these methodologies. In India, so far, very little has been done for proper disposal of these wastes.

There have been lots of environmental effects associated with oil and gas production[3]. The drilling fluids and muds generated in this process contain various chemicals. So their disposal into sea or on the ground along with the mud causes serious environmental problems for marine life, flora, fauna and human beings.

The drill mud generated can be categorized under these heads: water based mud, oil based mud and synthetic muds[1]. Water based mud are those where water is the liquid continuous phase; oil based mud are those where oil is the liquid continuous phase and synthetic based mud are those in which the mineral oil component is replaced by artificial oil-like substances such as ester, ethers, alginates, *etc*. Few of these compounds[1] are listed in Table-1.

TABLE-1
DIFFERENT TYPES OF MUDS USED DURING DRILLING OPERATIONS

Types of mud	Chemicals used
Water based mud	-Glycol based -Alkali silicates -Acrylamide homocopolymer -Carboxymethyl cellulose -Acrylamide copolymer -Propylene glycol -Metal lignosulphonates
Oil based mud	-Diesel oil -Palm oil derivatives (alternative to diesel oil) -Hydrated castor oil (viscosity promoter) -Maleated elastomers -Poly-α-olefins (Biodegradable in nature)
Synthetic based bud	-Ester -Ether -Poly-α-olefins -Linear alkylbenzene -Alginates-biological origin (estractyed from brown algae)

Recent literatures[4] show the impact of drilling operation on the environment. Hazardous waste amendment rules (handling and management, 2000) have been introduced by the Environment Protection Act of India. This emphasizes the need to specify the hazardous wastes generated by various types of industries. A guideline for the effluent generated by offshore subcategory (58 Federal Regulation 12454) has been published by USEPA on 4th March, 1993. This encouraged the use of less toxic drilling fluids and fluids which degraded faster. After careful considerations and calculating associated costs USEPA proposed the Effluent Limitation Guidelines[5]. Gillam *et al.*[6] conducted a review on the disposal options for cuttings contaminated with oil based drilling mud for use in Canadian Arctic. It has been concluded from the study that onshore treatment with incineration and landfill has the least environmental effect. Though oil based are technically superior to water based muds, but by optimized drilling, solid control through efficient equipments and good housekeeping practices, show that the cost of synthetic based muds can be brought to comparable levels[7].

The present work is based on the characterization of mud (contaminated with oil) generated at a drilling site in India and estimation of its energy content by incineration using the generated energy and final disposal of the drill mud in an environment friendly manner.

EXPERIMENTAL

Drill mud generated at site was collected from Nehru Environmnetal Engineering Research Institute, Nagpur, India while a project was going on. The characteristics of the mud were determined[1] at the drill site in the chemical laboratory. These are shown in Table-2.

TABLE-2
CHARACTERISTICS OF WASTE

Parameter	Range of existing values	Prescribed standards
pH	7.15-10.3	5.5-9.0
Total suspended solids (mg/L)	200-850	100
COD (mg/L)	500-800	100
BOD_5 (mg/L)	100-150	30
Chromium (mg/L)	Up to 8	1.0

A portion of the mud was used to determine the calorific value using the standard technique. The results have been given in Table-3.

TABLE-3
CALORIFIC VALUE OF THE WASTE

Test	Test value	Method of test
Gross calorific value	6540 cal/g 27.21 MJ/Kg	IS: 1448 (Pt-6), Reaff-1996
Net calorific value	6090 cal/g 25.49 MJ/Kg	IS: 1448 (Pt-6), Reaff-1996

Since there is lot of oil that remains within waste, attempt was made to determine the oil content. However, even after two extractions 10 % oil still remained with the waste.

Disposal of this oil containing waste was very difficult since it affects the environment. The volume, being too large, occupies a large area during disposal. As an option for disposal, incineration technology has been considered. This technology has the advantage of making the hazardous waste benign by high temperature treatment with simultaneous reduction in volume. Though opponents and advocates seem to be almost equally divided, but keeping in mind the amount of associated oil going as waste with heavy metal contaminations, incineration was chosen as the final method of disposal. The energy generated was estimated. Suitable options for the use of this energy generated by incineration of this waste were tried. Hence, calculated energy balance was done.

Calculations for energy balance: The calculations were based on an estimated average value of 30 % oil content by mass with net calorific value of 6090 cal/g (25.5 MJ/Kg), as obtained by analytical test.

Total solid waste generated = 1892 tons

Out of which,

Water = 131 tons
Oil = 568 tons
Solids = 1193 tons

Other standards which are taken into consideration are as follows:

Specific heat of drilling solids	= 0.84 KJ/Kg K
Specific heat of water	= 4.18 KJ/Kg K
Latent heat of vapourization of water	= 2260 KJ/Kg K
Specific heat of flue gases	= 1.1 KJ/Kg K
Initial temperature of wastes	= 25 ºC
Exhaust temperature of flue gases	= 500 ºC

The solid is assumed to be heated up to 1000 ºC. This oxidizes the heavy metals in the waste and render ash less toxic for ultimate disposal. The dry flue gas is assumed to escape the system at 500 ºC.

Total energy available in the waste would be equal to

$$Qt = [1892 \times 1000] \times 25.5 \times 10^6$$
$$= 48 \times 10^6 \text{ MJ}$$

where, 1892 = total solid waste generated (tons)
25.5 = calorific value of solids

Energy required for heating only the solids (1193 tons) would be

$$Qs = ms\,\Delta T$$
$$= (1193 \times 1000)\,[0.84] \times (1000-25) \text{ KJ}$$
$$= 0.98 \times 10^6 \text{ MJ}$$

Energy required for water superheating would be

$$Qw = ms\,\Delta T$$
$$= (131 \times 1000) \times 4.18 \times (100 - 25) \text{ KJ} + (131 \times 1000) \times 2260 \text{ KJ} + (131 \times 1000) \times (3500 - 2680)$$
$$= 0.45 \times 10^6 \text{ MJ}$$

Flue gases are composed of various components, mainly carbon, hydrogen and nitrogen. They combust in presence of oxygen to form their oxidized products. The ratio of atmosphere nitrogen to oxygen is 3.76 (79/21) by volume.

$$C + H_2 + xO_2 + x\ 3.76\ N_2 \longrightarrow CO_2 + H_2O + x\ (3.76)\ N_2$$

Assumed composition of gas is

Carbon = 88 %

Hydrogen = 12 %

Therefore, a = 88/12 = 7.33

b = 12/2 = 6

Hence, a + b/2 = 88/12 + 6/2 = 10.33

Dry flue gas formed per 100 Kg of fuel would be

$= 7.33 \times 44 + 10.33 \times 3.76 \times 28$ Kg

= 1410 Kg

Total dry flue gas

$= 1410 \times 568 \times 1000/100$

$= 8.0 \times 10^6$ Kg

Therefore, energy lost in dry flue gas would be:

Total dry flue gas × specific heat of flue gas × (exhaust temperature of flue gas-initial temperature of flue gas)

$= 8.0 \times 10^6 \times 1.1 \times (500 - 25)$

$= 4.18 \times 10^6$ MJ

The losses from radiation/convection is assumed to be 20 % of total energy available in the waste *i.e.*,

$= 9.6 \times 10^6$ MJ

If we assume other losses also, this may be due to:

- Incomplete combustion
- Moisture in air intake
- Unburnt carbons
- Ash and slag formation

This can be assumed to be a total of 30 %.

$= 0.3 \times 48 \times 10^6$ MJ

$= 14.4 \times 10^6$ MJ

Therefore, total losses in the system would be

$= (14.4 + 9.6 + 4.18) \times 10^6$ MJ

$= 28.18 \times 10^6$ MJ

Hence, Total energy required = Energy required for heating solids + Energy required for water superheating

$= (0.98 + 0.45) \times 10^6$ MJ

$= 1.43 \times 10^6$ MJ

Total losses required = Total losses + Total energy required

$= (28.18 + 1.43) \times 10^6$ MJ

$= 29.61 \times 10^6$ MJ

Net energy for useful purpose = 18.4 × 10^6 MJ

Air requirements: While designing the incinerator, the air requirement has also been calculated so as to maintain the required flow rate. In this case it has been calculated as shown below:

Mass of oxygen (air) supplied per 100 Kg of fuel

= 10.33 × 32

= 330.6 Kg

Because air contains 23.2 % oxygen by mass therefore

Mass of air per 100 Kg of fuel = 330.6 / 0.232 = 1425 Kg

Total air requirement would be = Mass of air per 100 Kg of fuel × Oil waste in total solid wastes generated

= 1425 × 568 × 1000/100

= 8.1 × 10^6 Kg

Depending upon the time required to incinerate, we can calculate the flow rate, for which 20 days uniform rate will come out to be 4-5 Kg per second of air requirement.

Options available for utilization of estimated energy

The energy that would be available from incineration of the oily wastes could be utilized in any of the following manner:

Power generation: Energy available in 20 d and assuming 20 % total conversion into electrical energy would be

$$= \frac{18.4 \times 10^6 \times 0.2 \times 10^3}{20 \times 24 \times 3600} \text{KW}$$

= 2000 KW of power (approx.)

Total installed load of the rig is 4700 KW. From collected data it has been observed that maximum load required at rig was 1200 KW while drilling at a depth of 3477 meters. So the power available from incineration would be sufficient to take the load of the rig.

Domestic use: Indian household for domestic consumption uses the following fuels. Their calorific values have been shown in Table-4.

TABLE-4
ENERGY CONVERSION

Fuel	Calorific value (MJ/Kg)	Fuel	Calorific value (MJ/Kg)
Coal	27.714	Fuel wood	19.6
Soft coke	24.900	Animal dung	10.2
Kerosene	35.700	Agricultural waste	14.8
Charcoal	29.100	–	–

Attempts were made to calculate if the generated energy from incineration of oily wastes could replace the domestic fuels partially or fully. For safety it was assumed that the conversion efficiency is 10 %. Many rural household use kerosene as the fuel. The amount of kerosene used for domestic cooking, which could be saved by utilizing the total energy generated from wastes, has been calculated.

Calorific value of kerosene = 35.7 MJ/L

$$\text{Kerosene equivalent} = \frac{18.4 \times 10^6 \times \text{MJ} \times 0.1}{35.7}$$

$$= 50 \text{ tons (approx.)}$$

Assuming 50 L kerosene consumption per household per month, this generated energy would be sufficient for 100 household for 10 months.

Process water heating: For this 20 % conversion efficiency is assumed. The mass of water can be heated to 80 ºC from 20 ºC.

$$\text{Mass of water} = \frac{18.4 \times 10^9 \times \text{KJ} \times 0.2}{4.187 \times 60 \times 20}$$

$$= 700 \text{ tons/d (approx.)}$$

Energy could be spent for heating the required amount of water. Since so much hot water is not required, generated energy could be used for the production of hot water as well as for power generation.

Conclusion

Incineration has been considered as the most viable option of the oily drill mud generated by oil exploration. This would, not only, generate energy but also reduce the volume and reduce the toxicity by high temperature degradation so that disposal of the ash would be easier and environment friendly. The main problem with incineration is that it goes to very high temperature. Hence the system should be placed at a far off place from the drill site to avoid any fire disaster. Drill mud has to be transported to the incinerator. Generated energy from incineration can find use at various places. Some of the options for utilization of energy have been discussed in the paper.

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