

# Treatment Of Crude Oil Contaminated Drill Cuttings

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**ABSTRACT** The oil content, which was found to be the main contaminant in drilling wastes from various oil producers, was measured in this study using retort analysis. The oil-contaminated drill cuttings were then treated using a Low Thermal Desorption Process. Following treatment, the recovered cuttings were examined for residual oil levels and associated contaminants using retort testing and other globally recognized techniques. An average residual oil content of 0.7% in the treated material was found to be in compliance with Department of Petroleum Resources (DPR) standards, which is significantly below the DPR regulatory threshold of 1%. These findings suggest that the Low Thermal Desorption Process has great potential as a remediation method for reducing drilling waste pollution in the Niger Delta region of Nigeria.

**Keywords:** Thermal Desorption, Oil Content, Retort Analysis, Oil and Gas, , Drilling Fluid, Drill Cuttings

## Introduction

The world today depends majorly on petroleum and its products for various industrial applications. Petroleum is drilled using drilling mud's or fluids and tier additives without which oil companies could not drill for oil or gas. During oil and gas exploration and exploitation activities by-products are formed and they are called petroleum drilling wastes. In many areas of Nigeria's Niger Delta, where petroleum production and exploration are concentrated, these wastes pose serious environmental problems. These are undesirable byproducts that are produced and released during different phases of oil and gas drilling operations. While it is illegal in Western Europe, Nigeria, and many other parts of the world to discharge petroleum wastes or drill cuttings contaminated with oil-based muds (OBMs) and synthetic-based muds (SBMs), there are still issues with insufficient regulation and enforcement. The effects on marine ecosystems could be profound and biologically significant if oil and gas production facilities and exploration rigs are allowed to dispose of drilling waste without adequate control. Oil residues and hazardous drilling fluid components frequently contaminate drill cuttings released during offshore operations, posing increased environmental risks. Additionally, drilling cuttings may still contain substantial amounts of organic and inorganic materials even after mechanical separation and treatment in specialized facilities, especially when oil-based drilling fluids are used. As a result, there are significant worries about possible ecotoxicological disruptions in offshore production settings. Drilling fluid is an essential part of the drilling process and is needed in the wellbore to:

- move rock fragments to the surface from the drill bit.
- supply energy to the drill bit's downhole motor.
- preserve and condition fluid characteristics while it is circulating.
- allow cuttings to be separated on the surface in order to stop them from reentering the system.
- use fluid monitor, to deliver data on downhole conditions in real time.
- maintain subsurface pressure balance to stop well blowouts and fluid inflow.
- prevent collapse by providing support for the uncased wellbore walls.

Drilling fluids have "an extremely wide range of concentrations that cause different toxic effects" due to their variable composition and the wide range of situations in which they are used. Based on eco-toxicological hazard, drilling fluid components are categorized into three major groups.

1. Water-based muds (fresh or salt water can be used as the base)
2. Muds based on oil
3. Synthetic materials, including internal olefins, polyapha olefin, and vegetable esters.
4. Air and foam fluids

The majority of drilling muds contain a variety of chemical additives, with the exception of air and foam-based drilling fluids. The most important of these are:

- Weighting materials, such as barite, are added to the mud to increase its density and balance the pressure between the geological formation and the wellbore.
- Corrosion inhibitors, such as zinc carbonate, shield downhole metal equipment from formation fluids that are acidic.
- Dispersants (like lignosulfonates): Keep solid particles suspended so they can be transported to the surface by preventing their aggregation.

- Surfactants and flocculants, such as fatty acids, regulate foam and encourage emulsion stability in the fluid system.

Thermal desorption remediates contaminated materials through the application of heat, which volatilizes organic pollutants without oxidation. The fundamental reliance on volatilization means that process efficacy is a direct function of contaminant volatility. It is therefore highly efficient for volatile organic compounds (VOCs) and lighter hydrocarbons, whereas its performance diminishes with less volatile species, including high molecular weight polycyclic aromatic hydrocarbons (PAHs).

Low Thermal Desorption (LTD) systems are generally sufficient for treating wastes contaminated with light hydrocarbons, aromatics (such as benzene, toluene, ethylbenzene, and xylene, or BTEX), and other easily volatilized organic compounds. LTD systems normally operate in the temperature range of 250 °C to 350 °C. On the other hand, when treating wastes containing heavier hydrocarbons, like polycyclic aromatic compounds, high-temperature thermal desorption systems can achieve lower residual oil contents at temperatures as high as 520 °C.

Treated solids, water condensate, and oil condensate are among the secondary waste streams produced by the thermal desorption process. To choose the best recycling or disposal strategy, more research may be needed for each of these streams. Recovered liquid fractions can be separated and utilized again in drilling mud formulations in some applications, increasing the treatment process' overall economic feasibility. In other situations, further treatment could be required to reduce the possible negative effects of these by-products on the environment.

### Experimental Materials and Method

The experiment was conducted on oil contaminated drill cuttings obtained from five different oil wells operated by oil producing companies in Nigeria represented as X1, X2, X3 and X4. The samples were collected at One Oil and Gas free Zone where those companies convey their waste for treatment and disposal. The oil contaminated drill cuttings come on site in sealed containers called skips.

### Materials

- Retort machine
- Batch Samples: the samples were taken from each skip from the same company and were well mixed in an appropriate container to form a batch sample.
- Retort Analysis: the different batch samples will then undergo the retort test carried out in a high temperature unit.
- Oil-based mud drill cuttings samples collected from the following wells:
  - W1 operated X1
  - W2 operated X1
  - W3 operated X2
  - W4 operated X3
  - W5 operated X4

### Experimental Procedure

- I.) Sample is removed from the bottle and placed into a small cylinder. Then a retort analysis form is marked with date, time, and the name of the person taking the sample.
- II.) The sample is weighed (50g) and recorded on the retort analysis form.
- III.) The sample is then placed into a metal cylinder which in turn is placed into the retort machine.
- IV.) The metal container is then heated up to 350°C for a period of one hour. Due to this heating process, a liquid (a mixture of oil and water) is extracted from the sample of liquid that is collected in a glass container was weighed. The glass has level markings in millimeters (mm) on the side; thus, the separated oil and water readings were visible. Readings were taken from the glass container in order to determine the oil-water ratio that was used in the calculation. After which, the sample left in the retort machine was heated up to 500°C for another period of one hour and the reading process was repeated.

### Retort Analysis Calculations

Table 1 shows an example of batch sample retort analysis calculations for different temperature conditions.

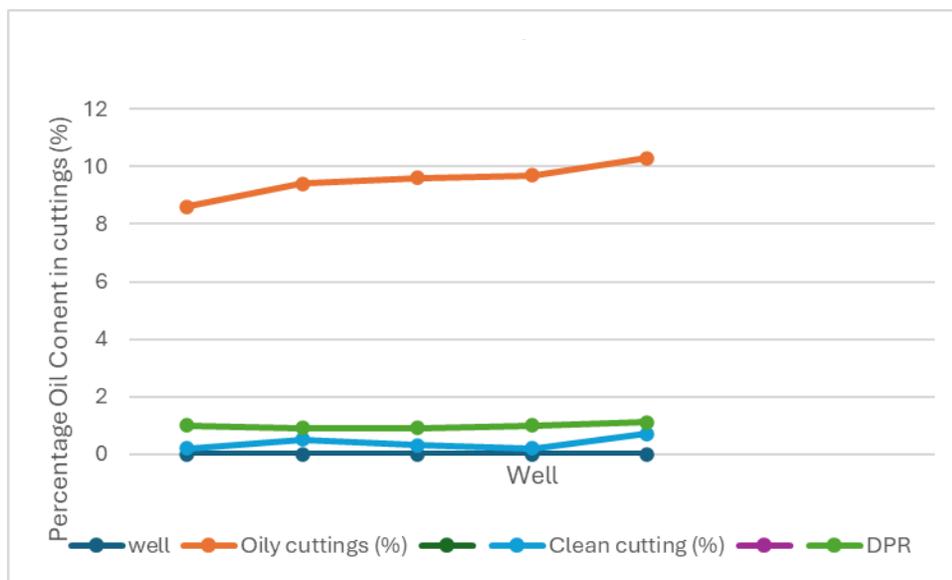
**Table 1:** Procedure for Retort Analysis

| Readings                                     | 350°C  | 500°C  |
|--|--------|--------|
| Empty Retort (ER)                            | 272.2g | 272.2g |
| Full Retort (FR)                             | 322.2g | 322.2g |
| Weight of Materials                          | 50g    | 50g    |
| Empty Glass (EG)                             | 71.0g  | 71.0g  |
| Full Glass (FG)                              | 79.3g  | 84.4g  |
| Weight of H <sub>2</sub> O (ml x I.O)        | 5.0g   | 7.0g   |
| Weight of oil and H <sub>2</sub> O (FG – EG) | 8.3g   | 13.4g  |

|   |      |       |
|---|------|-------|
| Weight of oil: (FG – EG) – Weight of H2O  | 2.2g | 6.4g  |
| Oil percentage = $\frac{(FG-EG)-Weight\ of\ H_2O}{Weight\ of\ material} \times 100$ | 6.6% | 12.8% |
| Oil percentage = $\frac{Weight\ of\ H_2O}{Weight\ of\ material} \times 100$         | 10%  | 14%   |

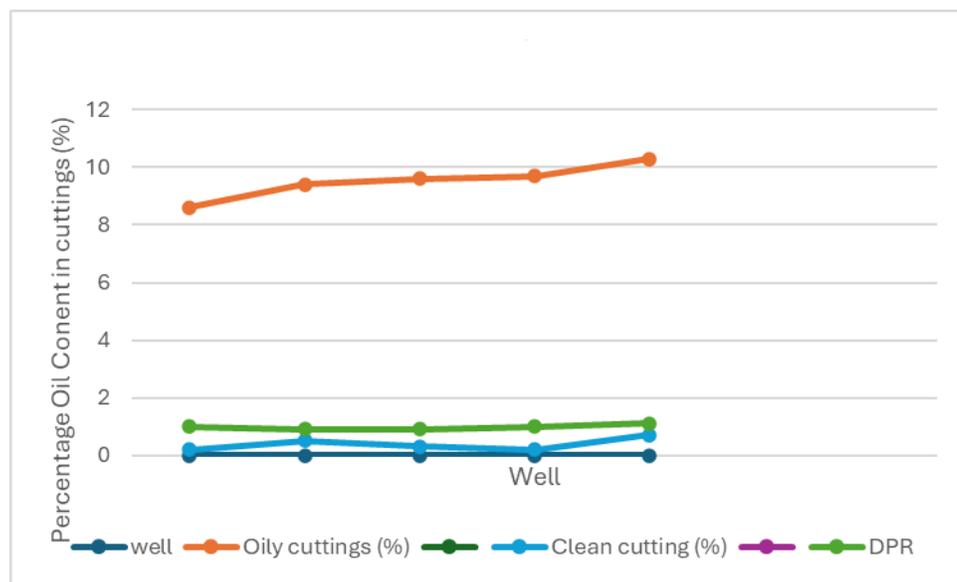
**Results and Discussion**

The purpose of the retort analysis on the different wells was to know before treatment, the oil (principally) and water contents in the oil contaminated drill cuttings.



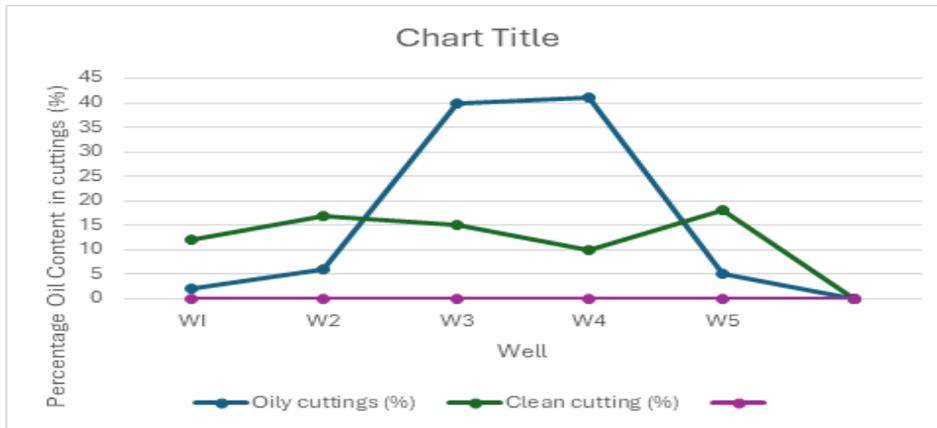
**Fig. 1: Percentage Oil Content in Drill Cuttings of Various Wells Before and After Treatment at 350°C**

Fig. 1 shows the percentage oil content of oily and cleaned drill cuttings of the various wells at 350°C. The oily (i.e raw and unprocessed) cuttings showed high percentage of oil content for all wells (with W5 been highest), which is above allowable limit (1%) set by the DPR. It is observed that after treatment, the oil content dropped significantly below the required standard by legislation.



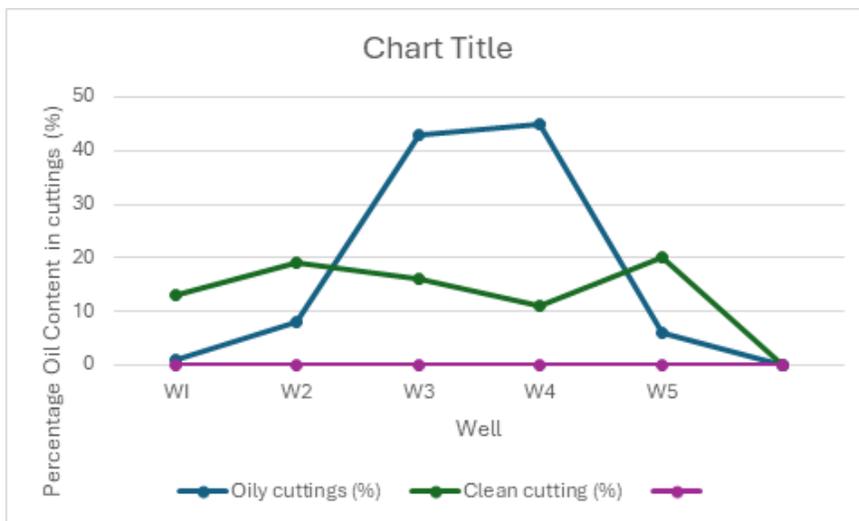
**Fig. 2: Percentage Oil Content in Drill Cuttings of Various Wells Before and After Treatment at 500°C**

Fig. 2 shows the percentage oil content of oily and cleaned drill cuttings of the various wells at 500°C. The oily cuttings showed high percentage of oil content (than those at 350°C) for all wells with W5 been highest, which is above allowable limit (1%) set by the DPR. It is observed that after treatment, the oil content dropped significantly below the required standard by legislation.



**Fig. 3: Percentage Water Content in Drill Cuttings of Various Wells Before and After Treatment at 350°C**

Fig. 3 shows the percentage water content of oily and cleaned drill cuttings of the various wells at 350°C. The oily (i.e raw and unprocessed) cuttings showed high percentage of water content for W3 and W4 wells and lower percentage for W1, W2 and W5 wells. It is observed that treatment, the water content for W3 and W4 while those for W1, W2 and W5 increased. Water contents for all the cleaned drill cuttings ranges between 10 – 20%.



**Fig. 4: Percentage Water Content in Drill Cuttings of Various Wells Before and After Treatment at 500°C**

Fig. 4 shows the percentage water content of oily and cleaned drill cuttings of the various wells at 500°C. The oily cuttings showed high percentage of water content for W3 and W4 wells and lower percentage for W1, W2 and W5 wells. It is observed that treatment, the water content for W3 and W4 while those for W1, W2 and W5 increased. Water contents for all the cleaned drill cuttings ranges between 10 – 20%. This means the water quantity is been standardized automatically during treatment process. The samples of the cleaned cuttings were analyzed in the laboratory using internationally satisfied tests methods to ascertain if the level of total hydrocarbons, heavy metals and chlorides in the residual materials were below those specified by the Department of Petroleum Resources (DPR). The cleaned cuttings of the selected wells average less than 0.7%, which is significantly below the statutory 1% limit set by the DPR for such materials to be considered as normal waste products (see Table 2). Therefore, after DPR approval has been granted the cleaned cuttings can be reused as a construction material or for land stabilization.

**TABLE 2: ENVIRONMENT LOGISTICS ANALYSIS RESULT FOR CLEANED DRILL CUTTINGS**

| Parameter                                   | Test method       | DPR<br>Limit | W1     | W2     | W3     | W4     | W5     |
|---|-------------------|--------------|--------|--------|--------|--------|--------|
| pH  | W104              | 6.5-12       | 9.05   | 8.56   | 8.75   | 8.68   | 8.61   |
| Electricity conductivity<br>(mmhos/cm)      | W107              | 8.0          | 7.86   | 7.89   | 7.32   | 7.895  | 7.13   |
| Salinity as Cl'(mg/1)                       | W104              | 5000         | 4750   | 4854   | 4600   | 4785   | 7.13   |
| Arsenic As (mg/1)                           | W135              | 5            | <0.2   | <0.2   | <0.003 | <0.003 | <0.002 |
| Barium, Ba(mg/1)                            | W135              | 100          | <0.004 | <0.006 | <0.008 | <0.010 | <0.005 |
| Cadmium, Cd(mg/1)                           | W135              | 1.0          | <0.04  | <0.004 | <0.002 | <0.020 | <0.001 |
| Chromium, Cr.(mg/1)                         | W135              | 5.0          | <0.002 | <0.002 | <0.002 | <0.030 | <0.002 |
| Lead, Pb(mg/1)                              | W135              | 5.0          | <0.01  | <0.01  | <0.01  | <0.120 | <0.01  |
| Mercury, Hg(mg/1)                           | ASTM M03 223      | 0.2          | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| Silver, Ag(mg/1)                            | W146              | 5.0          | <0.009 | <0.01  | <0.001 | <0.001 | <0.001 |
| Zinc, Zn(mg/1)                              | W135              | 50           | 8.468  | 8.925  | 7.58   | 9.755  | 7.825  |
| Vanadium, V(mg/1)                           | APHA 31148        | -            | <0.04  | <0.04  | <0.04  | <0.012 | <0.04  |
| Selenium, Se(mg/1)                          | W135              | 1.0          | <0.07  | <0.007 | <0.001 | <0.001 | <0.001 |
| Nickel, Ni(mg/1)                            | W135              | -            | <0.002 | <0.002 | <0.004 | <0.110 | <0.004 |
| Sodium, Na(mg/1)                            | AAS               | -            | 868.0  | 858.0  | 838.0  | 857.0  | 825.0  |
| Magnesium, Mg(mg/1)                         | AAS               | -            | 52.0   | 50.0   | 54.0   | 56.0   | 51.0   |
| Sodium Adsorption Ratio (SAR)               | Spectrophotometer | 12.0         | 11.245 | 11.845 | 12.21  | 11.786 | 11.530 |
| ESP(%)                                      | Spectrophotometer | 15.0         | 13.560 | 12.862 | 13.52  | 13.754 | 12.760 |
| Cation Exchange Capacity(CEC)<br>(meg/100g) | Titrimetric       | -            | 26.780 | 13.635 | 13.48  | 12.874 | 13.625 |
| Oil and Grease (%)                          | W130              | <1.0         | 0.230  | 0.108  | 0.410  | 0.135  | 0.378  |
| 1PH(%)                                      | W131              | -            | 0.102  | <0.001 | 0.230  | 0.010  | 0.120  |
| Calcium, Ca(mg/1)                           | AAS               | -            | 850.0  | 870.0  | 946.0  | 746.0  | 856.0  |

**W1 = Work instruction based on “American Society for Testing and Materials” ASTM 20<sup>th</sup> Edition 1999 and American Public Health Association” APHA 20<sup>th</sup> Edition 1998)**

### Conclusions

The study revealed that Thermal Desorption Process is an environmentally reliable and cost-effective solution for treatment of materials contaminated by hydrocarbons. With regards to the treatment of drill cuttings contaminated by oil-based mud, the thermal desorption process showed reduction in the hydrocarbon content of all treated cuttings to less than 0.5%. This quantity is well below the environmental limits set by most existing legislation (e.g. DPR).

The study also showed the uniqueness of the Low Thermal Desorption Process such that it retrieves hydrocarbons from the treated materials without altering the molecular structure of the processed hydrocarbon. The process produces three end products; Oil, Water and Soil. The work instruction based on American Society for Testing and Materials (ASTM) and American Public Health Association (APHA) prescribed procedures were followed in analyzing the content of impurities. About 95% of the oil in an incoming drill cutting is recovered and that ensures an optimized treatment process in relation to the Low Thermal Desorption Unit volumetric treatment capacity.

|                                  |             |
|----------------------------------|-------------|
| <b><u>Incoming Processed</u></b> |             |
| <b>10% Water</b>                 | <b>9.5%</b> |
| <b>Recovered Oil</b>             |             |
| <b>10% Water</b>                 | <b>10%</b>  |
| <b>Recovered Water</b>           |             |
| <b>80% Solids</b>                | <b>80%</b>  |
| <b>Recovered Solids</b>          |             |
| <b>Oil Residue in Solids</b>     | <b>0.5%</b> |

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