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[1.]B. O. AKINNULI, [2.]S. P. AYODEJI, [3.]O.O. OJO

RECLAMATION OF BASE OIL FROM OIL WELLS DRILL CUTTINGS AND ITS DISPOSAL ECOLOGICAL HAZARD CONTROL

[1,2,3.]Department of Mechanical Engineering, Federal University of Technology, Akure, Ondo State, NIGERIA

Abstract: The discharge of oil-based drill cuttings to open sea has been adjudged to cause acute and sub-lethal toxic effects such as smothering of seabed life (due to the formation of cuttings piles), poisoning of aquatic life (due to the presence of toxins), and eventual ecological disruption/eco-toxicological disturbances of offshore environment. Equally, oil based drilling fluids are desirable for drilling explorations but they are generally expensive; as a result, their recovery from drill cuttings has the outlook of offering economic benefit to oil and gas industries. In order to circumvent the possible dangers of drill cuttings and to recover oil based drilling fluid for reuse purposes, the treatment of oil-contaminated drill cuttings becomes indispensable. Thermal desorption facility of Warri Refinery in Delta State, Nigeria was employed for this study. Drill cuttings are removed by circulating the drilling fluid over mechanically controlled equipment such as shale shakers, high speed centrifuge, vortex dryers and thermal desorption system. The composition analysis of materials after treatment reveals 80% solids and 10% recovered base oil which is of high economic value. The Thermal Desorption Unit (TDU) process recovers between 10-12 m^3 of oil in every treated 100 tons of oily cuttings.

Keywords: investigation, reclamation, oil base cuttings, composition analysis, hazard control

INTRODUCTION

The Delta Basin of Nigeria is significantly rich in paraffinic and low sulphur crude oil; and this has encouraged oil explorations in the deepwater and continental shelves of low Niger parts (Niger-Delta expanses) of Nigeria. As a result, petroleum hazardous wastes come with the oil exploration activities in this region. However, drilling operations have been adjudged as the major source of these wastes. Apart from produced water, drill cuttings represent the greatest amount of discharges from petroleum related drilling activities [1].

As it is well known, oil and gas explorations and drilling operations require the use of drilling fluids as the drill bit is advanced to the preferred earth depth. This is to facilitate proper cutting process. Thus, when the fluid is introduced through the drill string and injected under high pressure through nozzles at the drill bit, it cools and lubricates the drill bit, maintains hydrostatic pressure on the formation and stabilizes the borehole wall [2]. As the drill bit rotates and advances into the formation, small pieces of rock are broken off and they are then flushed from the borehole along the annulus between the drill string and borehole wall. Drilled muds which are viscous and complex formulation are ejected out of the borehole as well. The ejected mud includes finely divided materials such as ground ilemenite, bentonite, various clays, barite, lead ore, fibers, hulls and others in a liquid medium which may be aqueous (water or brine) or an oil (diesel oil) [3].

In general, three types of mud are currently used or produced during drilling operations; they include oil-based mud (OBM), this is primarily composed of diesel oil or mineral oil and additives; water based mud (OBM) which consists of base salt water or fresh water containing additives; and the third is synthetic-based mud (SM) which has oil-like base materials [4]. The water-based muds are not able to perform in high temperature conditions. Synthetic-based muds generally perform better than water-based muds but less than oil-based muds. Oil-based muds are well suited for high temperature conditions because oil-based muds are paraffinic in nature with a relatively high boiling range [5, 6]. At the earth's surface, the drill cuttings are separated from the drilled mud through the use of various mechanical solids control equipment such as shallers, high speed decanter or centrifugal mud cleaners and vortex dryer [7]. As a result, the separated drill cuttings consist of mixtures of base oil, pulverised material, speciality chemicals, sediment and reservoir/basin rock fragments [8] [9] [10] [11]. In addition, hydrocarbons and higher concentration of metals such as Ba, Cr, Cu, Ni, Pb, and Zn [9] are major constituents of the drill cuttings. Therefore, there is a need to decontaminate the cuttings and recover base oil from them.

However, oil-based drill cuttings (OBDC) are hazardous solid wastes generated from drilling operations [12].

The deposition of solid drill cuttings forms hydrocarbon contaminated cuttings piles (distinct anthropogenic legacy) underneath hundreds of oil platforms/sea beds as a result of oil exploration and production activities [10] [13]. This occurrence smothers seabed life and most importantly reduction in oxygen and anoxia development within the sediment piles occur due to microbial mediated diagenetic reactions in organic-rich cutting piles [10].

Likewise, drill cuttings initiated weaker faunal response in the works of Hilde et al. [14] while Hilde et al. [15] investigated the role of physical disturbance in effects of water-based drill cuttings on benthic ecosystems. It was revealed that drill cuttings caused significant reduction in the number of taxa, abundance, biomass and diversity of macrofauna. Katsiaryna et al. [16] conducted laboratory investigation on phytoplankton aggregates and it was observed that drill cuttings significantly affected the physical characteristics of phytodetritus.

These drilling waste/cuttings must be treated because it cannot be discharged directly into a disposal site, not only because of their adverse effect upon the environment, but additionally because of the great value of oil contained in them. It has been a common practice to treat the oil drill cuttings in order to produce a solid material that can be disposed into the environment without injury to it.

Few works have been carried out on the treatment of drill cuttings. Marina et al. [17] carried out microwave radiation treatment of drill cuttings contaminated with synthetic drilling fluid. It was reported that n-paraffin was successfully removed from the contaminated cuttings. Likewise, Robinson et al. [18] reported that drill cuttings can be efficiently microwave-treated under optimized conditions. Robinson et al. [19] revealed that higher microwave power and electric field strength influenced the mechanism of oil removal from drill cuttings. However, total decontamination of oil from the cuttings was achieved during microwave dry remediation of oil contaminated drill cuttings by Irineu et al. [20].

On the other hand, Reginald et al. [21] worked on the stabilization/solidification of drill cuttings for forage production (elephant grass) in acidic soils. The stabilized/solidified drill cuttings were observed to improve the height and leaf lengths of the forage.

Also, supercritical water oxidation of oil-based drill cuttings is also another approach of treating contaminated drill cuttings [12]. Chaillan et al. [22] revealed that the efficiency of bioremediation process of contaminated soil with drill cuttings is dependent on the inherent degradability of HC compounds. However, remediation of oil-based drill cuttings through a biosurfactant-based washing and biodegradation treatment was achieved by Ping et al. [23].

Basically, thermal/mechanical technologies are preferred and used to ensure proper treatment and recovery of base oil from drill cuttings. Although, there are other technologies involving chemical processing as highlighted above but thermal/mechanical processing has proven to be the best over time. Thermal technologies use high temperature to reclaim or destroy hydrocarbon-contaminated drill cuttings. It is the most efficient treatment for destroying organics, and it also reduces the volume and mobility of inorganics such as metals and salt [24].

Thermal treatment can be an interim process to reduce toxicity and volume and prepare a waste stream for further treatment or disposal (such as landfill, land farming and land spreading), or it can be final treatment process resulting in inert solids, water and recovered base oil; the latter is the case with drill cuttings [25]. The thermal treatment technology is usually set up in a fixed land based installation, but can be made to be mobile to fit uses in an offshore rig platform if necessary but nonetheless large size and weight coupled with limited processing capacity have limited its use off shore. The cost for thermal treatment ranges from $75 to $150/ ton, with labor being a large component [26]. George and Smith [27] grouped thermal treatment technologies into two. The first group uses incineration (such as rotary kilns, and cement kilns) to destroy hydrocarbons by heating them to very high temperatures in the presence of air. Incineration is not commonly used for drilling cuttings because there is literarily no good recovery for the base oil. The second uses the thermal desorption principle, in which heat is applied directly or indirectly to the drill cuttings to vaporize, volatile and semi volatile components (base oil, water) without incinerating the oil.

In some thermal desorption technologies the off-gases are combusted but in the case of drill cuttings where the base oil has to be recovered, the thermal phase is separated to recover the hydrocarbon (base oil) [28]. Pierce and Wood [29] and Ritter [30] state that the attachments of thermal desorption technologies include direct/indirect rotary kilns and hot oil processors, thermal phase separation, thermal plasma volatilization, and modula thermal processors. In the case of drill cuttings treatment, thermal phase separation is the type of thermal desorption unit used.

The treatment of drill cuttings with thermal desorption unit has both economic and ecological benefits. For instance, thermal desorption process will facilitate the protection of the environment from hazardous oil-base drill cutting deposition and the recovery of water which can be retreated and put to use especially in arid regions. Similarly, the recovered soil with an oil residue of less than 0.5% can be sold to construction companies and used for road construction and building of houses or used for land filling and land spreading. Consequently, this paper examines the thermal desorption processing of drill cuttings obtained from the Delta-Basin of Nigeria. The recovered oil from the TDU was analyzed and compared to untreated base oil in order to identify the effect of TDU process on the reclaimed oil.

METHODOLOGY

Containment of drill cuttings such as synthetic (pseudo) oil based cuttings and other drilling waste in skips at the drilling/well sites is the first major operation.

However, the process for separating drill cutting from the oil-based drilling fluid starts from the well site with the use of mechanical solids control equipment prior to the transportation of the resultant residue to the waste management facility where thermal desorption technology is applied to recover the base oil from the contaminated drill cuttings.

A typical sample of drill cuttings observed under microscope is shown in Figure 1.

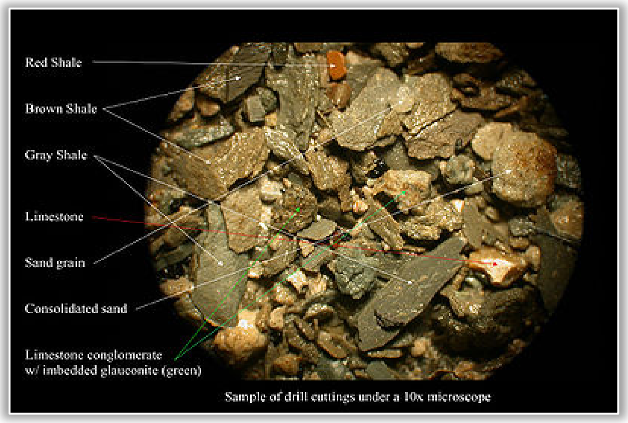

Figure 1: Sample of drill cuttings observed under microscope (drill cuttings)

The overall methodology employed for the waste treatment and oil recovery process is grouped into two which are primary and secondary treatments respectively. The primary treatment system involves the use of drilling platform solids-control systems to initiate solid separation at the well site. These systems employ shale shaker and centrifuge in their solid separation processes. Afterward, the secondary treatment is followed and this involves the handling of pre-treated cuttings (from the primary treatment facility) in cuttings dryer and thermal desorption unit.

These two methods of secondary treatment are employed to reduce drilling fluid retention on cuttings (ROC). Base oil recovery and extraction of environmental friendly drill cuttings are performed by the thermal desorption unit (TDU). The process separates incoming material (contaminated drill cuttings) and produces products like organic oil, water and pre-dried material. For instance, the employed thermal desorption unit feed system is shown in Figure 2 while its schematic diagram is illustrated in Figure 3.

Figure 2: Thermal desorption unit feed system

The incoming contaminated waste is fed to the feed hopper of the TDU. Subsequently, adjustable and controlled feeding is obtained by means of screw conveyers and gas sluices leading to the central processing unit as illustrated in Figure 3. The processor is a specially designed rotary heat exchanger which is heated by a closed loop circulation of thermal fluid (boiler) heat. Thus, gaseous hydrocarbons and steam leaves the processor by means of a lower over pressure into the controlled condensation stage where liquefying is achieved. The liquid phase is collected in a separation tank; and consequently, condensed oil/organic and water are separated and pumped away respectively. Consequently, the percentage and composition analyses of the recovered oil with respect to the inlet tonnage of cuttings were carried out. However, section 2.1 gives the detailed descriptions of the compartments and procedures of the TDU employed for this study.

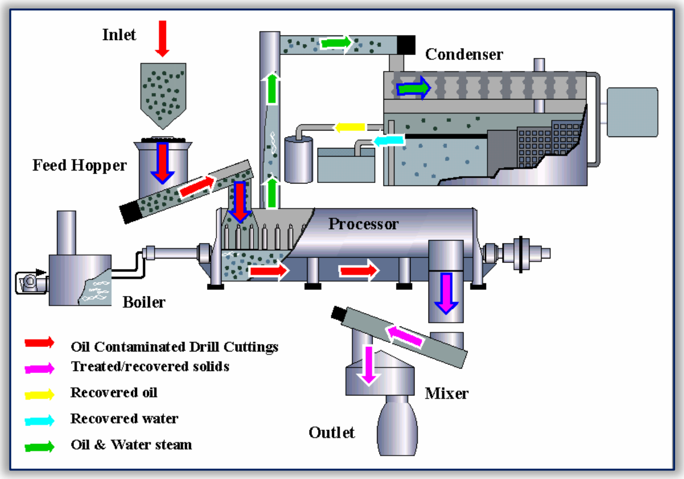

Figure 3: Schematics of the Thermal desorption unit (TDU)

THERMAL PROCESSING PROCEDURES

The thermal processing procedures are as follow:

- The contaminated drill cuttings are fed into the feed Hopper of the TDU by using a rotary head forklift to empty drill cuttings skips into the inlet hopper of the TDU;
- Material to be processed is then fed into the TDU through a single screw conveyor system attached to the TDU unit as shown in Fig 3. The heart of the TDU is a horizontal vessel with a rotating heat exchanger located inside. The heat exchanger is comprised of a hollow shaft and vein through which hot rotating fluid (hot oil) is pumped. The design provides a large surface area for heat transfer to the Oil Base Mud Cuttings (OBMC's) being processed. Paddles located on the periphery of the veins convey the OBMCs along the length of the processor as the heat exchanger rotates. The processor is capable of processing OBMCs at the rate of 20 to 40 tonnes per hour.
- The heat transfer fluid is heated by an 800kW diesel-fired boiler located within the processing system. The flow rate and temperature of the heat transfer fluid are controlled by a closed loop system to prevent degradation of the fluid. Emissions from the boiler are vented directly to the atmosphere through a 0.25m diameter stack discharging 3m above the roof level.
- Evaporation of the hydrocarbons and water contained within the raw material takes place as the OBMCs are heated to approximately to between 80 to 2800 C and

move from the inlet end towards the outlet of the processor. Air locks are fitted at both the inlet and the outlet of the processor to prevent the escape of the released vapours. To prevent a flammable mixture forming within the processor as the vapours arise, the processor is purged of any air using nitrogen prior to processing any raw material. The hot vapours realised from the raw material are then drawn through a vapour scrubber, where the steam and most of the hydrocarbons are condensed. Gases not condensed in the vapour scrubbers are directed to the boiler for incineration. In the event of a boiler malfunction, the non-condensable gasses will be diverted to an activated carbon filter.

- The mixture of water and hydrocarbon condensate generated by the process is separated into two streams by multi-stage settling. To minimize the potential for dust emissions from material handling operations, the cleaned solids arising from the process are moistened using the water recovered by the distillation. This recovered water accounts for the only wastewater generated by the process. There are no process water discharges to either public sewer or surface water.
- The condensed hydrocarbons arising from the process are stored in settling tanks that are housed within the processing building.
- The recovered water is reused in moistening and cooling down the solids at the outlet end of the treatment unit to prevent dusting effect. Excess recovered water is evaporated or can be condensed and used for other purposes if working in an arid region.
- The processed solids are collected.
- These solids are transported to the designated construction companies or are used in land filling or land spreading of swampy areas or lands with undulating topography.
- The recovered oil is collected in the designated temporary storage tanks.

RESULTS

The base oil from contaminated drill cuttings was recovered, the negative impact on the environment from the processing of drilling for hydro-carbons (Oil, and gas) was reduced, there was economic control of the drill cuttings (due to the high cost of base oil), the resource was conserved by reuse, pure drill cuttings that is void of contaminants and which can be sold off for land filling and engineering construction was produced.

The resultant drill cuttings oil content was brought below set standard by the government that is 0.5% compared to the acceptance standard of 1% oil in treated drill cuttings this is 50% improvement over the set standard. The result of the composition analysis of the materials after treatment is as shown in Figure 4.

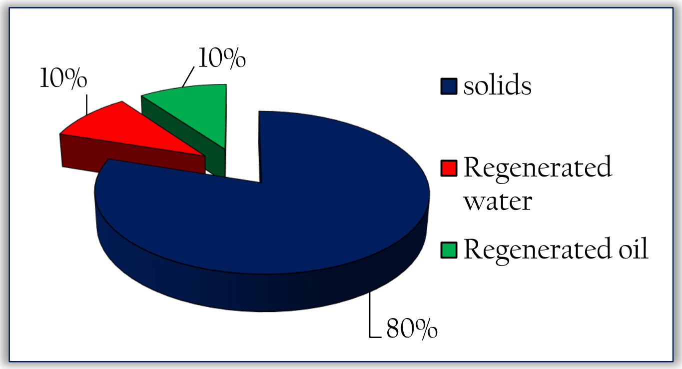

Figure 4. Composition Analysis of Materials

According to the chart provided in Figure 4, the composition assessment shows that 80% solid is obtained while oil residue in clean solids is less than 0.5% after thermal desorption treatment. Also, there is also 10% regenerated water and the recovered water in moistening and cooling down the solids at the outlet end of the treatment unit to prevent dusting effect. Excess recovered water is evaporated or can be condensed and used for other purposes if working in an arid region. Most importantly, there is 10% recovered base oil which as previously stated is of high economic value. However, Figures 5 and 6 gave the analysis of base oil before treatment and after treatment respectively.

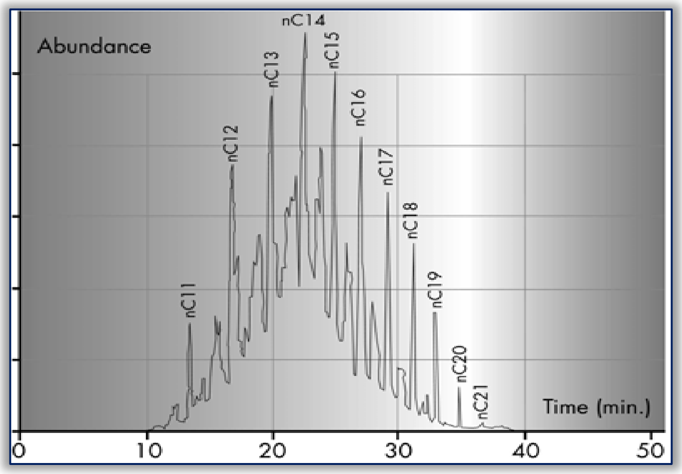

Figure 5. Analysis of base oil before treatment

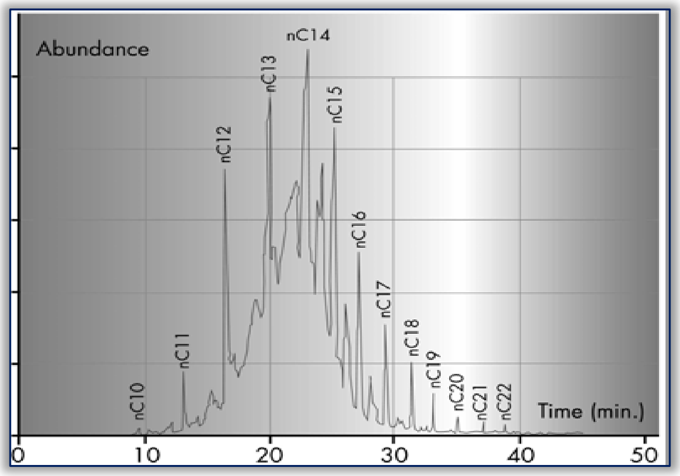

Figure 6. Analysis of recovered base oil after treatment

Similarly, Figure 5 and Figure 6 show that the structure/compositions of the recovered base oil have not been significantly altered by the thermal desorption separation process. This unchanged oil composition is one of the major advantages of the TDU processing and this occurrence is attributed to non-chemical induced treatment process. However, whenever the results are otherwise it is generally not acceptable.

Likewise, the LTDU process recovers between 10 -12 m3 of oil in every 100 tonnes of oily treated cuttings. The recovered oil is high quality oil which is suitable for reuse in the fabrication of new drilling mud. The employed TDU is capable of processing approximately 50 tons of cuttings per 24 hour period. However, if maintenance time is taken into consideration, the TDU has a capacity to process 70,000 tons of cuttings per annum. Routinely, the recovered base oils inclusions are Baroid XP-07, star AP Envirotec, EDC 99 and petrofree (Esters).

According to SPDC, the potential impact of drill cuttings can be reduced via Environmental management plan (EMP) to "as low as practically reasonable". Based on this study, one of the effective approaches for reducing environmental impacts or an effective ecological hazard control is thermal desorption of drill cuttings.

The treatment of Delta Basin drill cuttings in the thermal desorption unit (TDU) acts as an operative ecological hazard control process. Drill cuttings are obtained and transported to TDU for treatment instead of the perennial discharge to open sea. Thus, the formations of cutting piles and detrimental damage to the benthic communities of the Atlantics are utterly inhibited. Similarly, the cleaned or treated drill cuttings can be used for landfilling, as aggregate in construction, and as filler in bituminous mixtures as highlighted by Dhir et al. [31]. In addition, the recovered water from the TDU process can be retreated and use for other purposes.

CONCLUSION

Mechanical equipment based process or thermal desorption unit (TDU) has been effectively used in the treatment of contaminated drill cuttings and the recovered oil shows no significant variance with the untreated oil. This occurrence has been attributed to the predominant mechanical treatment process or non-chemical induced reaction of constituents of cuttings at elevated temperature. Consequently, environmental protection from the dangers associated with the disposal of well cuttings can be harnessed via thermal desorption processing.

Similarly, TDU has not only helped the oil and gas industries in complying with the laws of the Federal Republic of Nigeria but it has also retrospectively saved cost of drilling by reuse of recovered base oil. Economic benefit is expected from the successive drilling processes with the recovered oil. The treated final cuttings also have economic benefits especially for engineering construction and land filling.

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