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Treatment Efficiency of Drill Cuttings Using Thermal Desorption Technology

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Authors' contributions

This work was carried out in collaboration between both authors. Author OFJ designed the study and wrote the protocol. Author NBE performed the statistical analysis, managed the analyses of the study, wrote the first draft of the manuscript and managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Aim: The aim of this study was to analyze and determine the treatment efficiency of drill cuttings using the Thermal Desorption Technology.

Study Design: Drill cuttings were obtained from a work-over drilling operation with samples obtained at a depth of 2,750m from a typical well for this baseline study. The aim is to analyze the physical and chemical characteristics of the drill cuttings in a laboratory before and after the thermal desorption processes. A second drill cutting sample from another field location at the same depth of 2,750m was used for comparison during the analysis.

Place and Duration of Study: Port Harcourt, Rivers state, Nigeria (Laboratory analysis was done at Anal Concept Ltd, Port Harcourt, Rivers state, Nigeria and the thermal desorption unit is situated at the Initiates Plc, Etche LGA, Rivers state, Nigeria).

Methodology: A representative sample feedstock of cuttings was collected before and after the thermal treatment. The drill cutting sample was taken from a mixing tank by using a cup and auger. The samples of the cuttings were made for each case of the grab samples, and the samples later transferred into 500mL glass bottles. The sample contaminants were analyzed in a chemical laboratory using standard methods for determining the pH level, Electrical Conductivity, Moisture Content, Organic Pollutants and Heavy Metals.

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Results: The result showed significant reductions in all the pollutant concentrations after the drill cuttings were treated with the Thermal Desorption Unit. Moisture Content (MC) and the Total Petroleum Hydrocarbon (TPH) decreased significantly by 86% and 93% respectively. The concentration of the combination of Benzene, Toluene, Ethylbenzene and Xylene (BTEX) reduced drastically by 98% and the heavy metals concentration levels were also reduced after treatment with the TDU. Also, the laboratory analysis result of the treated drill cuttings shows that the pH level, Electrical Conductivity, Moisture Content, Organic Pollutants and Heavy Metals concentrations did not exceed the recommended Department of Petroleum Resources (D.P.R) limits.

Conclusion: This research reveals that the thermal desorption technology is the most economical, efficient and environmentally friendly method of waste management due to its contaminant removal efficiency. This method enhances product recovery and subsequent recycling which helps to reduce environmental impact and prevent economic losses.

Keywords: Thermal Desorption Unit (TDU); drill cuttings; thermal efficiency.

1. INTRODUCTION

Drill cuttings are fragments of rock that are usually present in millimeter size. They are produced from the subsurface of rocks when the drilling bit cuts into the formation during drilling activities and it is mixed with drilling fluids as a lubricant and also for cooling the drilling bits during the oil well drilling activities [1]. The cuttings are mixed with drilling fluid which contains a variety of chemicals to optimize the drilling, and then transported to the surface by the circulation of drilling fluid during drilling operations and separated by shale shakers or by cyclone separators. The fluid can be used again, but the drill cuttings are considered as waste, and were therefore traditionally being discharged to the seabed regardless of its chemical content [2]. Handling this waste is of great concern in the industry due to the significantly negative impact it has on the environment in relation to the amount of organic and inorganic toxic materials in them. A range of oil waste handling methods have been researched on and experimented in a bid to change the contaminants and sludges arising from oil drilling and exploitation activities into inert materials which renders the cuttings biologically and environmentally safe [3]. For example, management is a very necessary part of an oil drilling activity, be it on land or offshore location. These wastes materials that normally include used drilling fluids, formation cuttings and wellbore clean-up fluids are toxic in nature and must be properly treated before they are finally discarded [4].

The drilling fluid can be classed into three main types, water-based (WBF), pseudo/synthetic-based (SBF) and oil-based (OBF) drilling fluid. Oil-based drilling fluid was used and discharged to sea until the 1990s, but after 1993 it was prohibited to discharge this type of fluid to the sea due to its negative environmental impacts [5]. Even though the drilling fluid and cuttings are separated, some drill fluid will still adhere to the cuttings and thereby be discharged together with the cuttings. After some time, the cuttings will eventually build up as a pile and may store up at the base of the platform footings [2].

When drill cuttings piles are removed from their present location, the contaminants within the pile will be whirled up in the water body and might spread out over a large area. The contaminants will then be more available to species, and potentially pose negative impacts on the environment in the sediment and water column. The pollutant parameters assessed in the drilling cuttings are those recommended by Department of Petroleum Resources (DPR) which include the physicochemical indicators such as Electrical Conductivity and Moisture Contents, the organics such as Benzene, Toluene, Ethylbenzene and Xylene (BTEX) and Total Petroleum Hydrocarbon (TPH). Other pollutants also covered include heavy metals like Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Vanadium, Zinc and Barium. The adverse environmental effects of discharging these wastes from the petroleum prospecting industries untreated are of great ecological concern, as observed by Atlas and Bartlia (1993) [6], and many other researchers.

Hazardous waste generated from drill cuttings is a major challenge faced by the Niger Delta region which has the industrial hub for oil and gas activities in Nigeria. Improper management of these drill cuttings has resulted to the release of toxic contaminants which in turn affects the health of the inhabitants and the environment where they are finally disposed of [7].

The proper management of drill cuttings involves, among other methods, the use of thermal desorption technique to separate and recover wastes; a process that results in three streams which are water, oil and solid [7]. The heating involved in this method makes the liquid volatile and the vapor temperature is lowered and disintegrated into oil and water [8-9].

The aim of this study was to analyze and determine the treatment efficiency of drill cuttings using the Thermal Desorption Technology.

2. MATERIALS AND METHODOLOGY

2.1 Thermal Desorption Unit (TDU) Facility

A thermal desorption unit (TDU) in Rivers State was used in this study. It is specially manufactured and designed to treat drill cuttings and other oilfield hydrocarbon-contaminated wastes. The facility has successfully handled various oily contaminated wastes in line with regulatory protocol and approved limits.

The TDU system comprises of the following components:

- Feed screw conveyor and inlet tipping valve;
- Rotatory drum;
- Pugmill for rehydration and discharge auger;
- Vapour recovery section;
- Oil water separating system (OWS);
- Water treatment unit;
- Recovered oil unit; and
- Control center for instrumentation, electrical and process monitoring.

2.2 TDU Operational Treatment Range

The operational treatment ranges of the TDU were as follows:

- Rotary drum (kiln) waste feed temperature of 400°C to 550°C;
- Rotary drum (kiln) residence time of 10minutes to 40 minutes;
- Rotary drum treated waste exit temperature of 350°C to 400°C; and
- Final waste discharge temperature of not more than 100°C.

2.3 Waste Handling Procedure

The waste handling procedure used in this work was in accordance with that of Initiate Group, owners of the TDU, and in compliance with the DPR regulation. The procedure includes:

- Waste location surveillance visit;
- Waste collection;
- Waste manifestation;
- Waste transportation; and
- Waste tracking.

2.4 Waste Treatment Procedure

At the TDU site, the drill cuttings were analyzed to get the operating conditions which were used by the TDU plant for its treatment. The TDU treated the raw drill cuttings by initially extracting the hydrocarbons that are the main contaminants in the drill cuttings. The resulting hydrocarbons were then separated from the drill cuttings thereby leaving the powdered residues in an inert condition. The thermal desorption unit equipment as located at the Initiates Plc, Etche LGA, Rivers state, Nigeria and it's mechanism is as shown in Figs. 1 and 2.

2.5 Chemical Characterization of Waste

The chemical characterization of cuttings was structured to comply with the Department of Petroleum Resources (DPR) requirements (DPR's Environmental Guidelines and Standard for the Petroleum Industry, Revised Edition 2002) as stated in Table 1. The chemical characterization of the cuttings drilling wastes was conducted before and after the thermal treatment using standard methods for examination of water and wastewater [10]. The parameters tested were pH, moisture contents, electrical conductivity, heavy metals (Cd, Cr, As, Cu, Hg, Ni, Pb, V, Ba and Pb) and organics (Benzene, Toluene, Ethylbenzene, Xylene (BTEX)) and Total Petroleum Hydrocarbons (TPH) guided by Table 1.

2.5.1 Waste sampling

A representative sample feedstock of cuttings was collected before and after the thermal treatment as shown in Figs 3 and 4. The drill cutting sample was taken from a mixing tank by using a cup and auger. The samples of cuttings were made for each of the cases of the grab samples, and the samples later transferred into 500mL glass bottles.

Fig. 1. Thermal desorption unit
(Source: Vulcan® Drying Systems Thermal Desorption Unit)

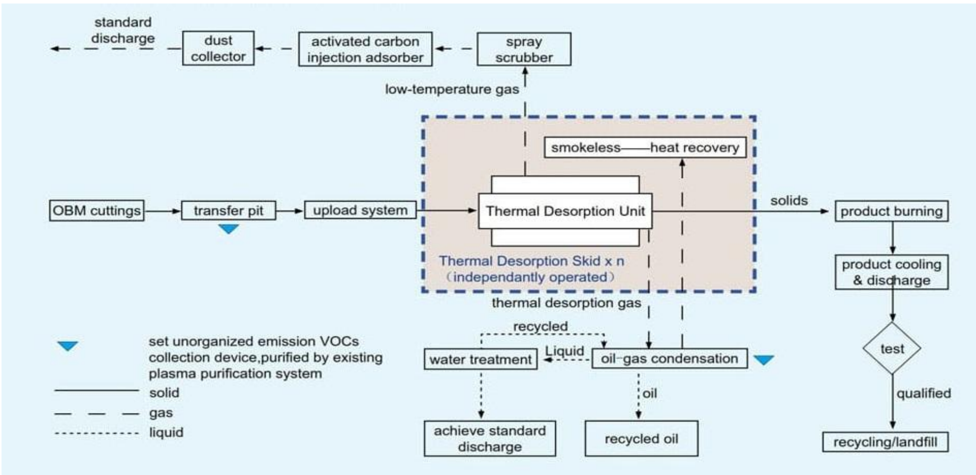

Fig. 2. Thermal desorption drill cuttings flow chart diagram
(Source: https://www.h-screening.com/thermal-desorption-drill-cuttings-treatment-system/)

Fig. 3. J.1. Sample of drill cuttings before treatment

Table 1. DPR limit of chemical characteristics of drill cuttings

Element/ Compound	Parameter/Unit	DPR LIMIT
Acid/Base	pH	6.5-9.0
Electrical Conductivity	EC (mmhos/cm)	8
Moisture Content	MC (%)	50
Total Petroleum Hydrocarbon	TPH(mg/kg)	-
Benzene, Toluene, Ethylbenzene and Xylene	BTEX (mg/kg)	-
Arsenic	As (mg/kg)	5
Cadmium	Cd (mg/kg)	1
Chromium	Cr (mg/kg)	5
Copper	Cu (mg/kg)	-
Lead	Pb (mg/kg)	5
Mercury	Hg (mg/kg)	0.2
Nickel	Ni (mg/kg)	-
Vanadium	V (mg/kg)	-
Zinc	Zn (mg/kg)	50
Barium	Ba (mg/kg)	100

Fig. 4. J.2. Sample of drill cuttings after treatments

2.5.2 Determination of pH

100g of air-dried drill cuttings sample were passed through a 2mm sieve and afterwards, 50g of it were placed in a 100mL beaker. 100 mL of distilled water was added to it and the mixture was stirred with a glass rod and allowed to stand for 24 hours. The pH value was read off using a Corning pH meter (Model PH2601).

2.5.3 Determination of electrical conductivity

The electrical conductivity of the cuttings sample was read off using the conductivity meter. The filtrate obtained from filtering the suspension used for pH measurement was also used for conductivity measurement. The conductivity bridge used for the measurement was the beribboned conductivity model type cm- 21 Bridge. Conductivity is expressed as mmhos/cm [11].

2.5.4 Determination of MOISTURE CONTENT

Soil moisture content was determined by using an oven dry method in which samples were dried to constant weight and the difference in mass of wet and dry samples recorded and expressed in percentage.

In doing this, about 10g of wet soil sample placed in a container, weighed and its mass, Mw

recorded. The soil sample was then dried in an oven (105°C) for about 24hours until it became completely dry. Its dry mass M_D was determined and the water content calculated from the equation.

$$W= \frac{Weight\ Mass - Dry\ Mass}{Dry\ Mass} \text{ x } 100\% \quad (1)$$

$$MC= \frac{M-M}{M-M} \text{ x } 100\% \quad (2)$$

Where;
M= mass of the empty container
M_W= mass of wet soil + empty container
M_D= mass of oven dry soil + empty container

2.5.5 Determination of organic pollutants

The organic pollutants Benzene, Toluene, Ethylbenzene, Xylene (BTEX) and Total Petroleum Hydrocarbons (TPH) values were achieved using a Gas Chromatograph, aided by a Flame Ionization Detector (GC-FID).

2.5.6 Determination of heavy metals

5g of the sample was put in the digesting tube after adding 2ml of conc. $HN0_3$ and 6ml of conc. HCL (1:3 ratio). The samples were put into the digester for a period of 1hour at 100°C with constant stirring. After complete digestion, the samples were then filtered into a 100mL volumetric flask with the aid of Whatman No. 42 filter paper. Samples were made up to 50ml mark in the volumetric flask using distilled deionized water. The value of concentrations of the heavy metals in the supernatant solution were achieved with the use of a GBC Avatar 6600 (AAS), with air acetylene flame connected to it.

2.5.7 Determination of treatment efficiency of cuttings

The treatment efficiency of the process was derived by using the formula:

$$\frac{BT-AT}{BT} \text{x} \frac{100}{1} = TE\% \quad (3)$$

Where;
BT= Parameter before Treatment
AT= Parameter after Treatment
TE= Treatment Efficiency
The resultant Treatment Efficiency is expressed in %

3. RESULTS AND DISCUSSION

3.1 Treatment Efficiency of Sample “A” Drill Cuttings Before and After Treatment with TDU

Data plots as presented in Figs 5, 6, 7 and 8 shows the levels of the pollutants in the main drill cuttings (Sample A) before and after Thermal Desorption treatment processes. From the parameters indicated, the levels of all the pollutants decreased after TDU treatment apart from the pH (Acidity) and Electrical Conductivity. The moisture content (MC) decreased from 19.22mg/kg before the thermal treatment to 9.2 mg/kg after the thermal treatment as shown in Fig. 5. Organics comprising of Benzene, Toluene, Ethylbenzene and Xylene (BTEX) decreased from 0.7 mg/kg before treatment to 0.012 mg/kg after treatment as shown in Fig. 6.

The heavy metals such as Arsenic, Cadmium, Vanadium and Barium reduced from 0.12mg/kg to 0.07mg/kg, 1.5mg/kg to 0.89 mg/kg, 1.03mg/kg to 0.23mg/kg and 0.42 to 0.23mg/kg before and after the thermal treatment respectively as shown in Fig. 7 and Fig. 8. Chromium, Nickel and Copper decreased from 28.93 mg/kg to 4.36 mg/kg, 21.59 to 4.78 mg/kg, and 12.97 to 7.17 before and after treatment respectively as shown in Fig. 6. Lead and Zinc decreased from 58.13 mg/kg to 4.09 mg/kg and 46.77 mg/kg to 35.33 mg/kg before and after treatment respectively as shown in Fig. 6. Mercury was having a very negligible level of concentration which was below the measurement point of the spectrometer which is below 0.004 mg/kg.

The Total Petroleum Hydrocarbon (TPH) reduced from 1407.8mg/kg before treatment to 87.73mg/kg after the thermal treatment as shown in Fig. 9. Similar result was observed in sample B, as shown in Fig. 10.

3.2 Treatment Efficiency of Drill Cuttings

Majority of the indicator pollutants recorded high treatment efficiencies due to the thermal desorption of the constituent elements and compounds as shown in Fig. 11. The Moisture Content (MC) recorded 86.36% treatment efficiency while the Total Petroleum Hydrocarbon recorded 93.76% treatment efficiency. BTEX comprising of Benzene, Toluene, Ethylbenzene and Xylene jointly recorded 98.29% indicating that the constituent elements were drastically reduced to a negligible amount.

Chromium, Lead, Nickel and Vanadium recorded an average treatment efficiency of 84%, 92.96%, 77.86% and 77.66% respectively. Arsenic, Cadmium, Copper and Barium recorded an average treatment efficiency of 41.66%, 40.66%, 44.71% and 45.23%. Whereas Zinc recorded a very low treatment efficiency of 24.46 making it the lowest amongst the rest.

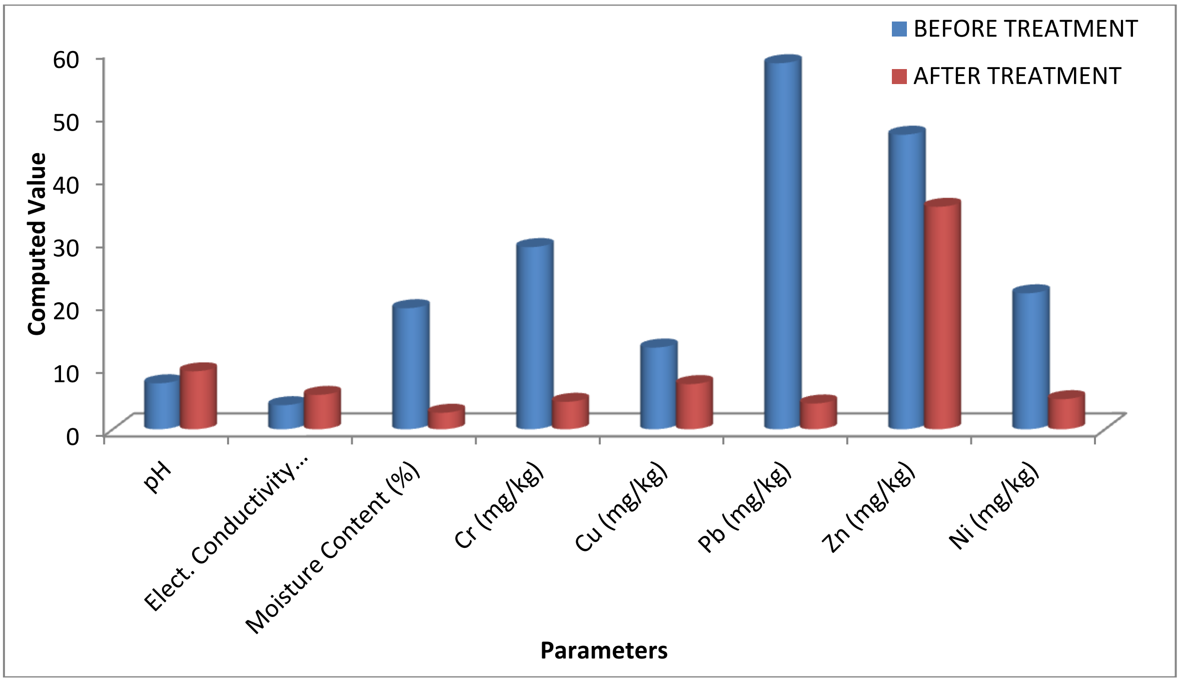

Fig. 5. Treatment chart of sampled parameters for sample A

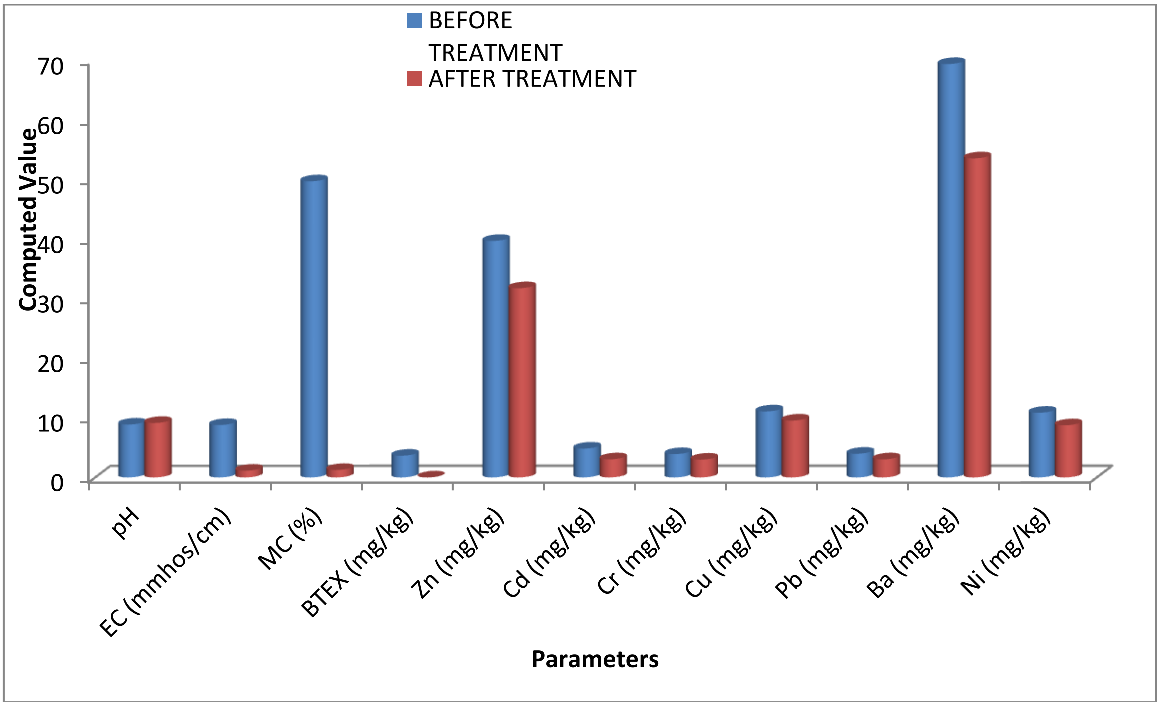

Fig. 6. Treatment chart of sampled parameters for sample B

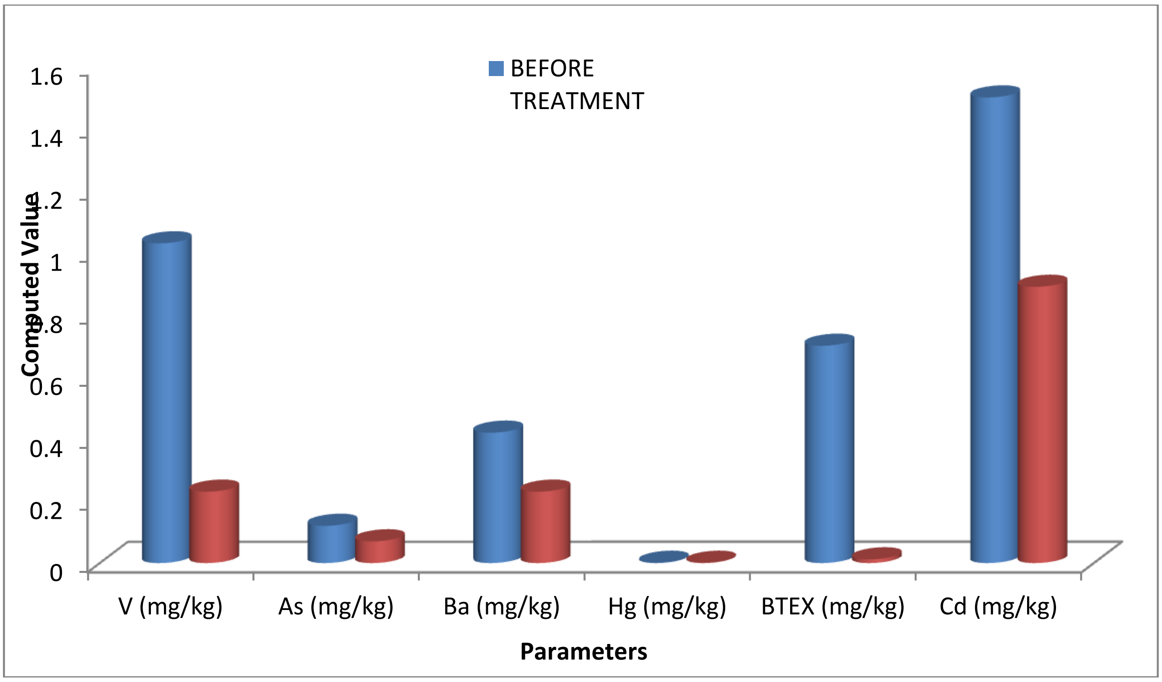

Fig. 7. Treatment chart of sampled parameters for sample A continues

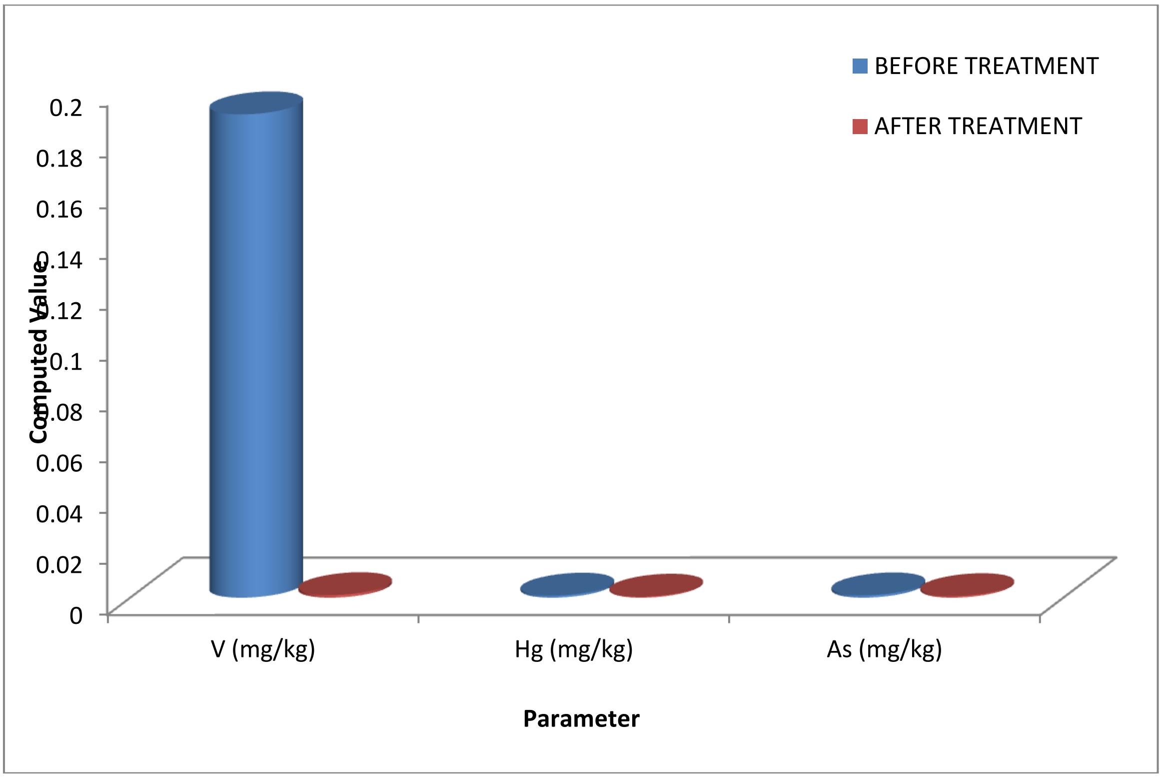

Fig. 8. Treatment chart of sampled parameters for sample ''B'' continues

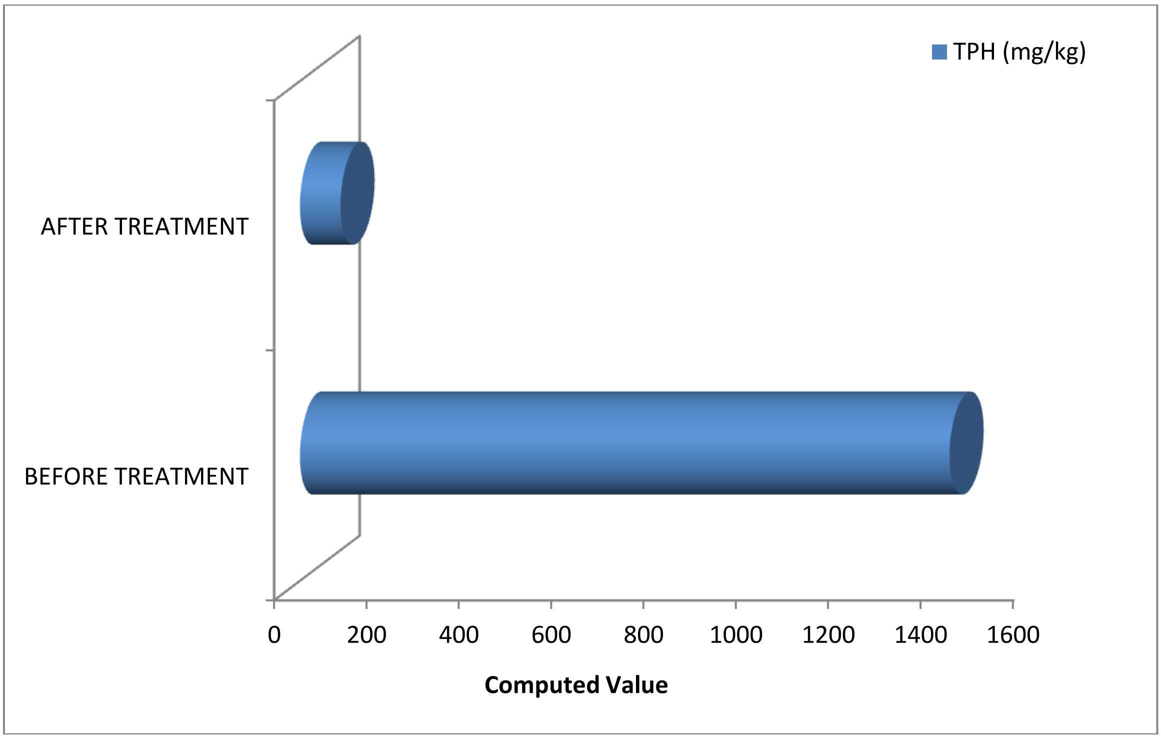

Fig. 9. Total petroleum hydrocarbon (TPH) Treatment Chart of sampled parameters for sample A

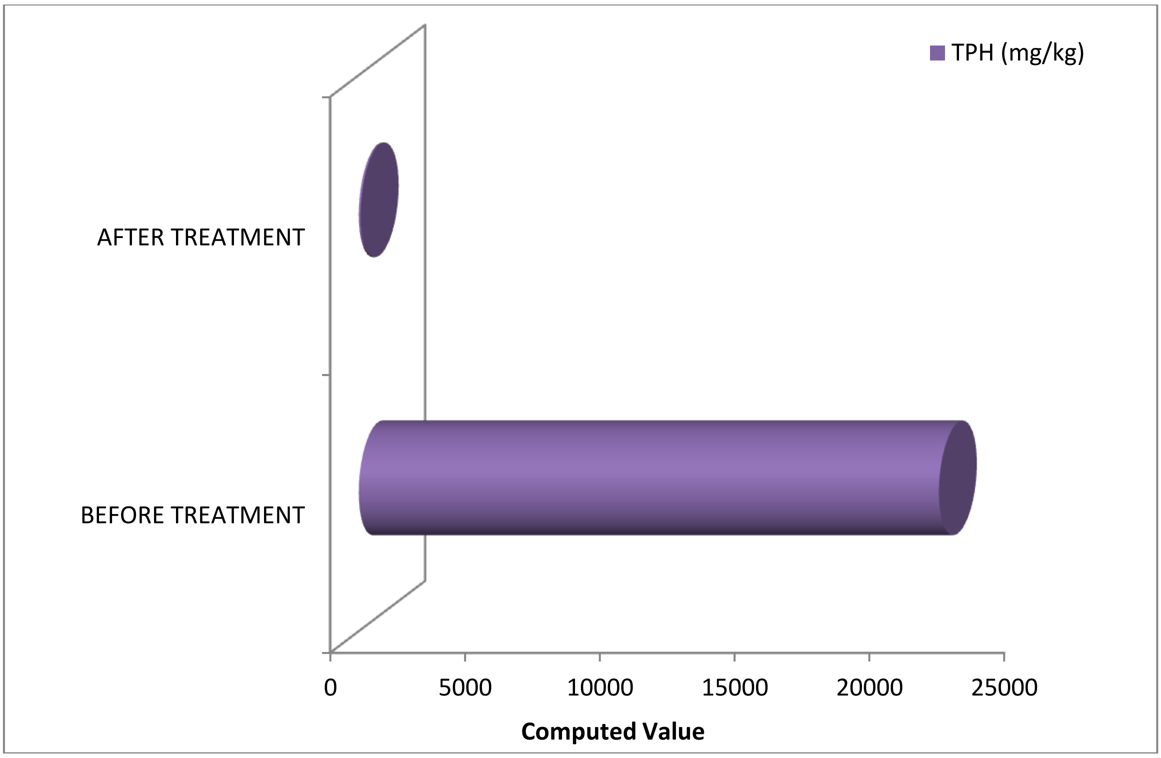

Fig. 10. Total Petroleum Hydrocarbon (TPH) treatment chart of sampled parameters for Sample “B”

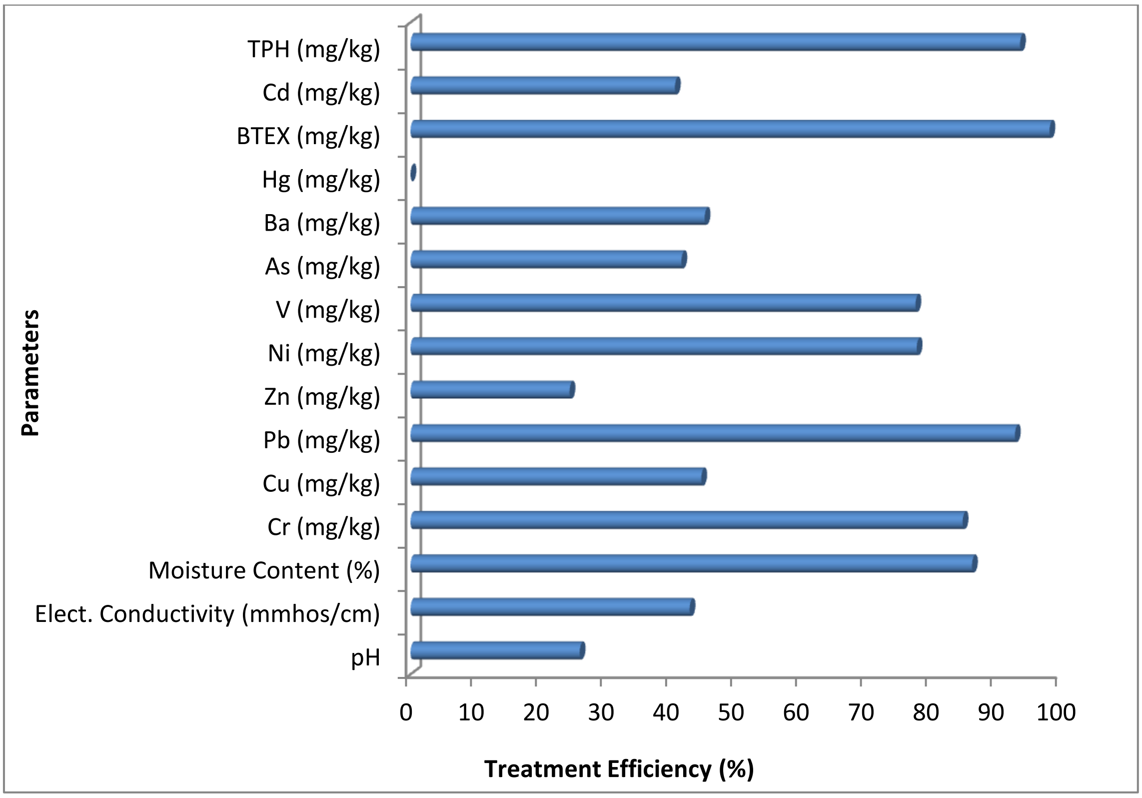

Fig. 11. Treatment efficiency chart of sampled parameters for Sample A

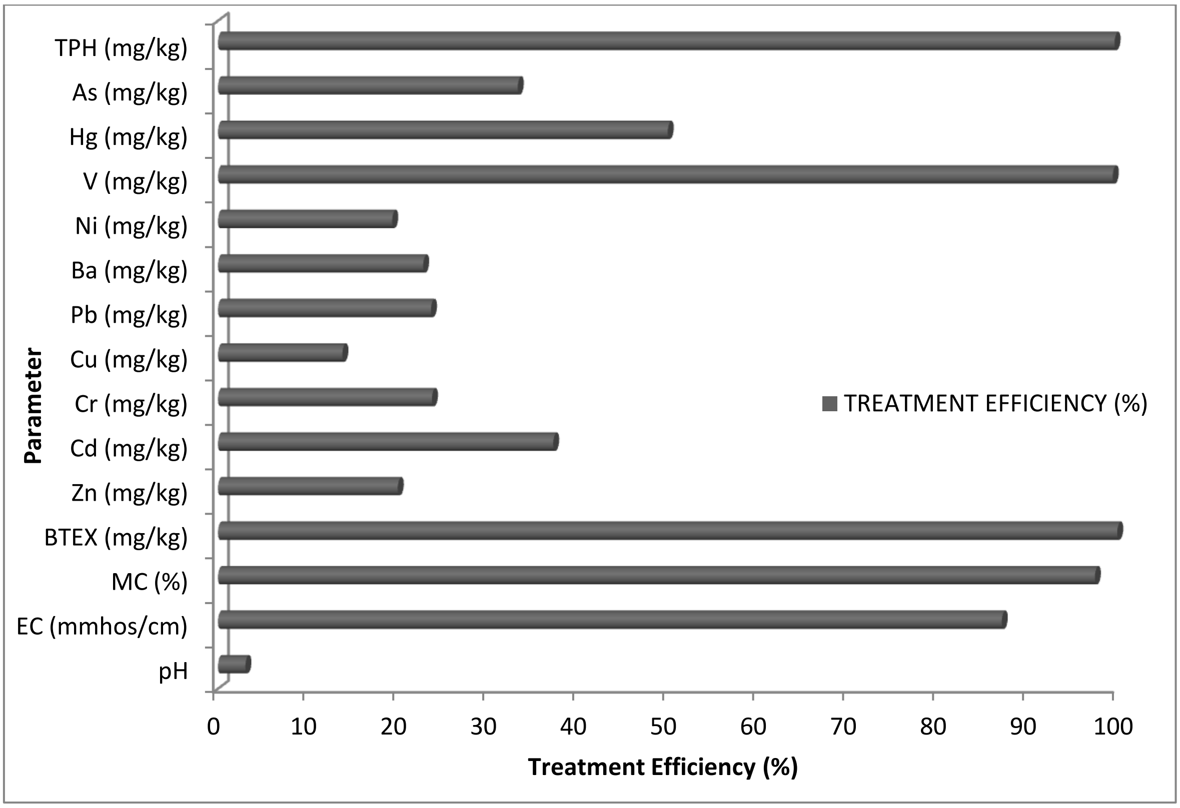

Fig. 12. Treatment efficiency chart of sampled parameters for Sample "B"

4. CONCLUSION

From the assessments made in this research, the following conclusions were deduced:

1) The use of the Thermal Desorption Unit (TDU) aids in neutralizing the harmful effects of the pollutants contained in untreated drill cuttings.
2) A single dose of untreated drill cuttings can cause severe damage to the human organs as well as the environment if not adequately treated.
3) Proper treatment of drill cuttings is essential due to the toxic effects of the pollutants to humans, animals, and the environment where they are finally deposited.
4) Significantly high treatment efficiencies of the drill cutting contaminants were recorded with the use of Thermal Desorption Treatment Technology.
5) Virtually all the resultant contaminants of the drill cuttings were reduced to a negligible level prior to the final disposal.

There are various methods of managing drill cuttings, but the thermal desorption technology has shown a high level of efficiency over others. This is reflected in its ability to retain the base oil that has a high market value.

This research shows that thermal desorption technique is the most economical, efficient and environmentally friendly method of waste treatment for drill cuttings. This method enhances product recovery and subsequent recycling which aids in reducing environmental impacts and further prevent economic losses.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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