Effect of Drilling Wastes on Urease Activities and Substrate Induced Respiration (SIR) in Wetland Soil of Delta and Bayelsa States, South-South, Nigeria

E. Mirinn[1], E. P. Berezi[1] and K. T. Nwauche[2*]

[1]*Department of Chemistry, Isaac Jasper Boro College of Education Sagbama, Bayelsa State, Nigeria.*
[2]*Biochemistry Unit, Department of Chemical Sciences, Rhema University, Aba, Abia State, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. Authors EM and EPB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors EM, EPB and KTN managed the analyses of the study. Author KTN managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The effect of drilling waste on urease activities and substrate-induced respiration in wetland soil of Niger Delta of Nigeria was investigated, using Fadama, mangrove and meander soils respectively. Urease activity and substrate-induced respiration (SIR) were measured after 1, 7, 14, 28, 42, 56, 70, 105 and 140 days of incubation to evaluate the effects of drilling waste on soil biochemical perimeters. Results obtained indicated that Fadama soil urease activities varied from 13.5 to 2.10 mg $NH_4 - Hg^{-1}$ dry soil in drilling waste. Mangrove soil varied from 13.5 to 2.22 mg $NH_4 - Ng^{-1}$ dry soil in drilling waste. Meander soil activities varied from 14.7 to 3.10 mg $NH_4 - Ng^{-1}$ dry soil in drilling waste. Also, the substrate-induced respiration in Fadama and mangrove soil range from 2.05 to 0.05 ml CO_2 kg^{-1} 24 h^{-1} in drilling waste respectively. Analysis of enzyme activities indicated positive relationship between urease activities and SIR (r = 0.78, $p \leq 0.05$ Fadama (r = 1, $P \leq 0.05$ Mangrove) and (r = 0.83, $P \leq 0.05$ Meander). There was also a positive relationship between 5%, 10% and 15% treatment levels in Fadama, meander and mangrove soils.

Keywords: Soil enzymes; Substrate-Induced Respiration (SIR); heavy metal; drilling waste.

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*Corresponding author: E-mail: nwauche_kelechi@rhemauniversity.edu.ng, nwauchekelechi@gmail.com;

1. INTRODUCTION

During drilling of oil and gas wells, special fluids are pumped down into the borehole to lubricate and cool the bit, float out cuttings, seal porous rock strata and apply hydrostatic pressure in the borehole from filling with water. Drilling fluids, commonly called drilling mud are prepared from a wide variety of components, although most water-base fluid contains barite ($BaSo_4$) betonite, chrome lignosulfonate, and lignite and sodium hydroxide. These components are mixed in varying proportions with water to produce drilling fluids with desired density and rheological properties. Upon completion of gas or oil well, the used drilling waste is normally incorporated into the soil adjacent to the well-site or allowed to dewater in a pit and covered with soil. Concern has been expressed recently about the short-term and long-term environmental effect of land disposal of drilling waste. Plants yields and soil properties may be adversely affected by the addition of drilling wastes due to alkalinity, salinity and trace elements or petroleum residue content of these wastes. Drilling fluid containing varying levels of trace elements such as Ba, Cd, Zn, Cu, Cr, Pb, Hg and As. Barium originates primarily from barite and chromium which is added in the form of chrome lignosulfonate (a common agent in drilling fluids). The other trace elements are present as contaminants in the barite or the drilling waste.

Land disposal of drilling wastes is a common practice in the Niger Delta region of Nigeria. In most cases, waste contractors collect these wastes from drilling sites and dispose of the waste in the community far away from the drilling site without prior assessment of the waste. These activities have hitherto heightened environmental activism and youth restiveness and host community cum oil company crises in the Niger Delta.

Drilling wastes in any form required characterization before land disposal to ascertain what quantity of contaminants is being added into agricultural lands and the adverse environmental impact. Heavy metals and poly-aromatic hydrocarbon (PAHs) are the most hazardous priority pollutants. They are ubiquitous in the various environmental systems and have resulted in much concern due to their toxicity, carcinogenicity and mutagen city. The literature on drilling waster effect on urease activities and SIR in wet-land soil in Niger Delta is grossly limited.

Current interest in assessing the quality of soil resources has been triggered by increasing awareness of soil as a component of the earth's biosphere. The soil has a role not only in the production of food and fibre but also in the maintenance of environmental quality. Thus, it is critical to define and evaluate the quality of soil resources. Conceptually, soil quality is defined as the capacity of soils to function within ecosystem boundaries to sustain biological productivity, to maintain quality of the environment and to promote plant and animal health [1] Soil biology is a significant component of soil quality and is the catalytic agent responsible for many of the transformations occurring in soil, most notably the reactions involved in nutrient cycling. Thus, it is meaningful to evaluate the biological aspect of soil quality within the context of overall system function [2].

In many arable agricultural soils, the soil microbial biomass is related to the soil organic matter content [3] and biomass carbon generally represents 2-3% of soil organic carbon [4]. Soils in Semiarid areas have very low microbial activities [5]. Low level of microbial biomass and low organic matter content. The last mentioned is due to the increased oxidation after cultivation, tillage operations that cause physical disruption on the soil surface, and erosion of topsoil rich in organic matter [6]. Thus, microbial biomass being the living part of soil organic matter can be a good index for comparing natural [7] and degraded [8] ecosystem.

More recently, molecular and physiological characterization of microbial community structure and diversity has advanced our understanding of soil quality [9,10,11,12,13]. Soil is a –living dynamic non-renewable, resources and its condition influence food production, environ-mental efficiency and global balance [14, 1,15,10]. The quality of soil depends in part on its natural composition and also on the changes caused by human use and management [15]. Human factors influencing the environment of the soil can be divided into two categories: those resulting in soil pollution and those devoted to improving the productivity of the soil [16].

There is a growing interest in the change in microbial community structure and diversity as a response to environmental stress [17,18]. The changes in microbial diversity may result in the changes in the soil function [19]. Petroleum hydrocarbons are the main pollutants of wetland soil in the Niger Delta area. Some component of

petroleum hydrocarbon has been identified as genotoxicants in a short-term mutagenicity test such as an Ames test, and animal carcinogens in a long-term carcinogenicity test [20,21]. The effects of petroleum hydrocarbons, especially polycyclic aromatic hydrocarbons (PAHs), on soil bacterial diversities have been reported recently [17,18,22].

Soil enzymatic activities mainly originate from soil microorganisms. Soil enzymes participate in many biological processes in soils and offer a useful assessment of soil "function". It can be taken as one of the indicators of soil health [14,23]. The impacts of heavy metals [24] and pesticides [25] on soil enzymes have been previously reported. Oxidoreductases, such as the widely studied dehydrogenase, hydrogen peroxidase and polyphenol oxidase, catalyze a wide range of oxidation-reduction reactions in the soil. Urease was chosen because it plays a key role in the nitrogen cycle, transforming urea to ammonium [25,26]. Soil respiration is one of the most common measurements of microbial mineralization and is taken as another important soil function [27]. The immediate respiration of a microbial community following a glucose addition is quantified in a manner avoiding significant contribution of cell multiplication [28].

Microbial activity can be analyzed on the bases of some parameters that reflect the behaviour of soil microorganisms, such as enzyme activity. The form of soil storage for later analysis has also been a source of concern for investigators. Skujins [13] discussed the effect of a different form of soil storage for the determination of enzyme activity and concluded that no rules can be established and that conditions differ for each soil and enzyme to be analyzed.

Soil enzyme activities have been suggested as suitable indicators of soil quality because (a) they are a measure of the soil microbial activity and therefore they are strictly related to the nutrient cycles and transformation; (b) they rapidly may respond to the changes caused by both natural and anthropogenic factors; (c) they are easy to measure [16,29,30,31,32]. Moreover, as claimed by several authors [14,33,34]. Soil enzyme activities may be considered early and sensitive indicators to measure the degree of soil degradation in both natural and agro-ecosystem. Thus, it's good to measure the impact of pollution on the quality of the soil. In this research, urease and SIR were chosen as the parameters to evaluate the effect of drilling wastes on wetland soil.

Soil enzymatic activities are related to soil function. The effects of drilling wastes on wetland soil enzymatic activities in the Niger Delta area have been scarcely studied. To understand if soil functions are affected by drilling wastes, soil urease activities and SIR in the Niger Delta area were evaluated in this study.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The Niger Delta area of Nigeria is located in the south-south zone of Nigeria. This zone lies between a narrow strip of beach ridges and a fairly extensive zone of the freshwater swamp. The Niger Delta is a wetland of about 70,000 square kilometres. It spreads over several ecological zones: sandy coastal ridges barriers, brackish or saline mangroves, freshwater permanent and seasonal swamp forests and lowland rainforest area has been cultivated leaving only the seasonal and permanent swamps as original vegetation. Subsistence farming and fishing is the mainstay of the people.

The Niger Delta area of Nigeria is a coastline of approximately 853 km facing the Atlantic Ocean. This coastline lies between latitude $4°10^1$ to $6°20^1$ N and longitude $2°45^1$ to $8°35^1$ E. The Niger Delta area is low lying with the height of not more than 30 m above sea level and is generally covered by freshwater swamp, mangrove swamp, lagoonal marshes, tidal channels, beach ridges and sand bars.

The Niger Delta Area of Nigeria is composed of four distinct geomorphological units namely the Barrier-Lagoon complex; the mud coast; the Arcuate Niger Delta; and the sand coast [35]. The vegetation of the Niger Delta area is also characterized by mangrove forests, brackish swamp forests and rain forests.

The ecosystem is particularly sensitive to changes in water quality, such as salinity or pollution and to changes in the hydrology of the region which is determined by the Atlantic Ocean and the flood region of the River Niger. The area is inhabited by some 1,600 long-settled communities. However, in recent times, economic activities, mostly the oil industry, have caused significant immigration of people to the area. The population is about twenty million. The

upland areas, particularly the urban centres are densely populated, while the swamps have scattered settlement taking advantage of higher grounds. Presently, the oil and gas industry drives the economy of the Niger Delta and to some extent Socio-economic development in the area.

2.2 Sample Collection

Drilling wastes were collected from an illegal dumpsite in Agbere, Bayelsa State, Nigeria with an auger. The drilling wastes were transferred to the illegal site by a contractor from Agip Samabiri/Biseni Flow Station and Cluster well.

Soil samples (0-20 cm) depth was collected with a soil auger from the meander belt soil in the Patani area of Delta State, Fadama soil between the Kwale and Ogume area in the same state and mangrove soil between Ogbia and Nembe in Bayelsa State all in the Niger Delta. The soil samples were collected with polythene bags and kept in a freezer (4°C) until transferred to Geography Departments, Delta State University, Abraka for proper identification before taken to the laboratory. The areas have no previous history of drilling waste dumps for the past 20 years. On reaching the laboratory, the soil samples were air-dried at room temperature of 25°C for 48 hours and sieved to pass 150 μm mesh.

2.3 Loading Intensity

Treatment of the soil was carried out in a ratio of 1:20, 1:10, and 3:20 drilling mud: soil sample. That loading was carried out as 5%, 10% and 15%.

1. 50 g of drilling waste per 1000 g of soil sample
2. 100 g of drilling waste per 1000 g of soil sample
3. 150 g of drilling waste per 1000 g of soil sample

A control was left which is a soil sample without treatment.

Before the amendment of the soil samples with drilling waste, the soil samples as well the drilling waste were separately analyzed for various physic-chemical properties. After which treated soil and control was kept in –a greenhouse

and brought out for analysis and assay of enzymes.

2.4 Physico-chemical Characteristics of Soil

2.4.1 Soil pH [36]

The soil pH was determined in soil suspension using a glass electrode pH meter with soil/water ratio of 1:5.

2.4.2 Particle: Size [37]

Soil particle size was determined using the pipette method.

2.4.3 Total phosphorus [38]

Total phosphorus was determined by Truog's Extraction.

2.4.4 Total organic nitrogen

Total organic nitrogen was estimated according to Miroslav and Vlandimir [38].

2.4.5 Nitrate (NO_3) copperized cadmium

It was determined by the reduction method [39,40].

Ammonium was determined by Indophenol Blue method [41].

2.4.6 Cation exchange capacity [42]

The cation exchange capacity of the soil sample was determined as the sum basic cations extracted neutral 1 M NH_4OAC and extractable acidity.

2.4.7 Total organic carbon

Total organic carbon was estimated by the method of Miroslav and Vlandimir [38].

Assay of Urease Activity: [43]

2.5 Determination of Ammonium Nitrogen Released

Five grams (5 g) of soil was placed in a 50 ml volumetric flask, 0.2 ml of toluene and 9 ml of tris (hydroxymethyl) aminoethane (THAM) buffer were added to it. The flask was swirled for a few seconds to mix the content. 1 ml of 0.2 m urea

Map 1. Map of Niger Delta, Nigeria
Source: channelstv.com

solution was added and swirled again for a few seconds. Then the flask was stopped and placed in an incubator at 37°C. The stopper was removed after 24 hours and approximately 35 ml of KCl-Ag_2SO_4 solution was added, swirled for a few seconds, and allowed to stand until the contents have cooled to room temperature (Ca. 5 min). The content of the flask was made up to 50 ml by adding KCl – Ag_2SO_4 solution. The flask was stopped and inverted several times to mix the contents. NH_4^+ - N in the resulting soil suspension was determine by pipetting a 20 ml aliquot of the suspension into a 100 ml distillation flask, NH_4^+ - N released was determined by steam distillation of this aliquot with 0.2 g MgO for 4 min.

Controls were performed in each series of analysis to allow for NH_4^+- N not derived from urea through urease activity. To perform control, the procedure described for assay urease activity was followed but made the addition of 1 m 1 of 0.2 M urea solution after the addition of 35 ml of Ag^2So_4 solution.

2.6 Substrate – induced Respiration Measurement [44]

One kilogram (1 kg) of soil was amended with 15 g of glucose and incubated for 24 hrs at 30°C. The CO_2 released from the 15 g of glucose amended soils after 24 hrs of incubation at 30°C was trapped in 20 ml of 0.1 $molL^{-1}$ NaOH and determined by titration with 0.1 $molL^{-1}$ HCl. Substrate induced respiration was expressed as ML CO_2 kg^{-1} dry soil.

2.7 Statistical Analysis

Analysis of all data was performed by ANOVA using IBN SPSS 2.6 for IBN SPSS Statistics (2010). The linear correlation coefficient was determined between different biological, physicochemical and biochemical parameters. Significance of all statistical analysis was accepted at an α 0.05.

2.8 Quality Control Assurance Procedure

The samples were carefully handled to avoid contamination. All samples containers and glassware were washed and soaked with 10% nitric acid for 48 hrs. All the reagents used in this study were of analytical grade or its equivalent.

3. RESULTS AND DISCUSSION

3.1 Physico-chemical Properties

The physicochemical properties of the soils from the three different locations are given in Fig. 1. From the result, the soils were found to be slightly acidic with pH ranges of 5.83-6.86. Fadama soil sample had the highest pH of 6.86; Meander had a pH of 6.68 while, Mangrove had a pH of 5.83. The electrical conductivity result of the soils showed that Fadama sample had the highest amount of ionic solutes. (116.30 μS/ cm) as EC is a measure of the amount of ionic solute in soil. Meander Belt sample had the lowest amount of EC. The highest amount of TOC and CEC (1.60% and 1.29 cmo 1/kg) were obtained

in Fadama sample. This was followed by the amount in the Mangrove Belt sample while the least amount was obtained in Meander Belt sample. The highest amount of anions were obtained in Meander Belt samples. Correlation data showed a significant positive correlation ($P < 0.01$) of pH CEC ($r = 1.00$) in the case of soil from the three different locations. There was also a positive correlation ($P < 0.01$) of ammonia with nitrate and nitrite.

The graph of the Physico-chemical parameters in the three soil samples are shown in Fig. 1 From the graph, it was observed that the highest amount of pH, EC, TOC, P, N and CEC were obtained in Fadama soil sample while the highest amount of ammonia, phosphate, nitrate and nitrite were obtained in Meander Belt soil sample.

The result of particle size analysis of the various soil samples is given in Fig. 2. It was observed that VCS for all soil samples was zero. The particle size results showed that Meander Belt and Fadama soils are sandy loam while Mangrove soil is silty loam. Correlation data showed a significant positive correlation ($P < 0.05$) of FS with VFS, sand with silt and clay with silt in the soil samples.

The graph of the particle size is shown in Fig. 2. From the graph, it was observed that Meander Belt soil had the highest amount of CS and MS, Fadama soil had the highest amount of FS while Mangrove soil had the highest amount of VFS. It was observed that there was no clay in the mangrove soil analyzed and that the soil was mainly silty. The sand content of Fadama soil was highest.

The physicochemical properties of drilling wastes sample analyzed – water base wastes and oil base waste are given in Fig. 3. The analysis result shows that drilling wastes samples were alkaline as their pH values were very high. The oil base waste had a higher pH value than the water-based waste. Also, the EC value of the oil base waste was higher. The TOC and P contents of the water base waste higher than the oil base waste content. All physicochemical analyzed in this study in the drilling waste samples showed a significant positive correlation ($P < 0.01$) with one another.

The graph of Physico-chemical properties of the drilling wastes is shown in Fig. 3. From the graph, it was observed that the values of pH, EC, N, CEC, Ammonia, nitrate, nitrite and EA in the oil base wastes are higher, while TOC and P-value in the water base waste were higher. All particle size parameters analyzed in this study in the drilling waste samples showed a significant positive correlation ($P < 0.01$) with one another.

The particle size analysis results of the drilling wastes are given in Fig. 4. The VCS and CS content of the water base waste was found to be zero. The MS and FS values of the water waste were found to be very low as compared with the values obtained in the oil base waste. This study showed that the water base waste is clayey while the oil base waste is sandy clay. The silt contents of the drilling waste were found to be low with higher silt content in oil base waste.

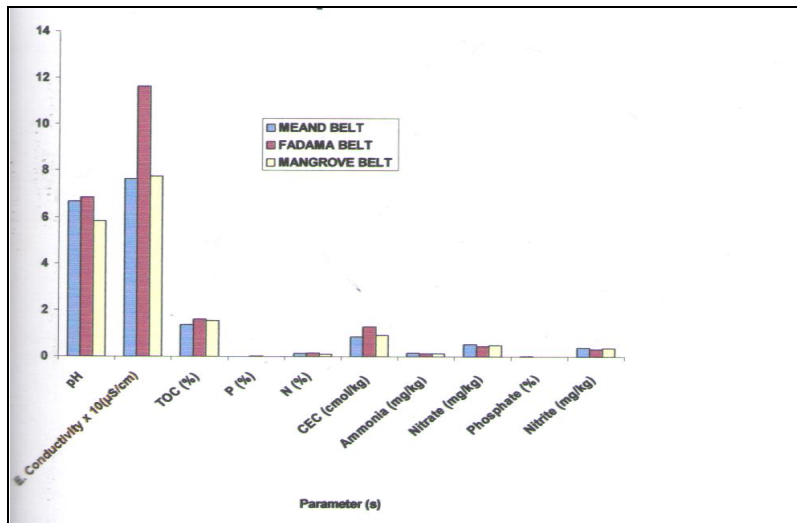The graph of the particle size content of the drilling wastes is shown in Fig. 4.

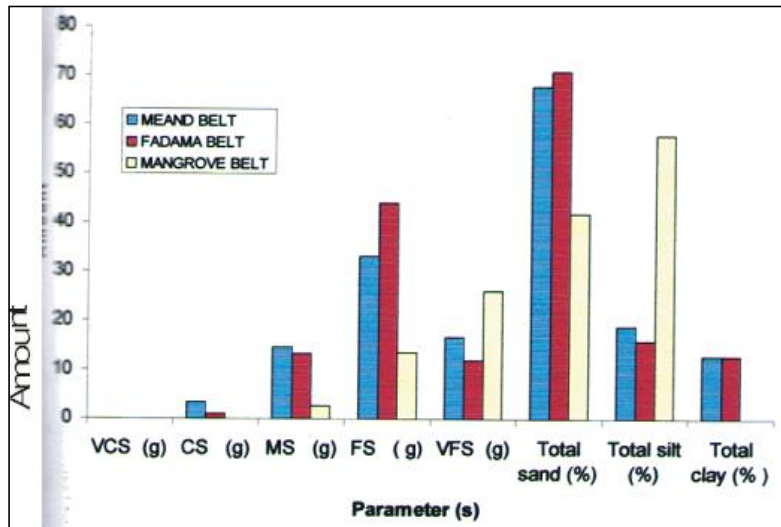**Fig. 1. Amount of some physicochemical parameters in soil samples**
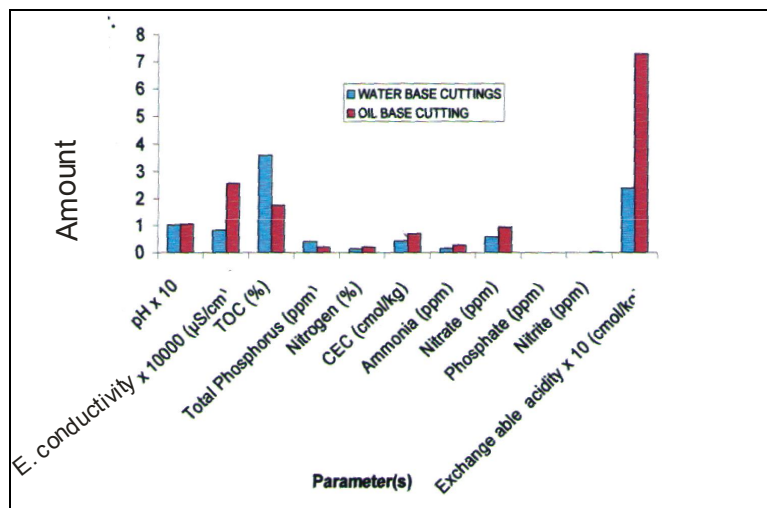
Fig. 2. Particles size of soil samples

Fig. 3. Physico-chemical properties of drilling waste samples

The metal contents result in Fig. 5 show that the drilling waste contains mainly iron with higher content in the oil base waste than the water-based waste. The amount of toxic metal in the drilling waste was not detected by the AAS equipment used for the analysis except Cr. Though its value is low.

Soils from the three different belts showed no differentiated range of physicochemical properties. Enzyme activities are generally considered to be a more direct expression of soil biological activity or the activities of specific processes of nutrient cycling and organic matter turnover, than measurements of microbial numbers [45]. It is believed to be a sensitive indicator of the effect of environmental factors on microbial functions [46]. The changes in the activities of urease enzyme in the three soils amended with drilling wastes at 5%, 10% and 15% rates are shown in Figs. 6, 7 and 8. Figs. 6, 7 and 8 show that soil urease activity was significantly changed after application of different doses of treatments (drilling waste during the incubation period).

Drilling waste, urease activity changed between 13.48 to 12.83 mgNH$_4$-Ng^{-1} soil 24 h^{-1} depending on the application doses on the first day. Soil urease enzyme activity value decreased from

3.25 to 2.10 mg NH_4-Ng^{-1} soil 24 h^{-1}. Fadama soil, 1.88 to 2.22 mg NH_4- Ng^{-1}soil 24h^{-1} mangrove soil and 3.24 to 3.10 mg NH_4-Ng^{-1} soil 24h^{-1} meander soil in drilling wastes amended soil depends on the treatment application doses and incubation time during the incubation period. This value was found not significant ($p > 0.05$) according to variance analysis. This decrease in urease enzyme activity may be due to some heavy metals in the drilling wastes.

This can be seen in the work of some authors. They proposed enzyme activity, especially dehydrogenase, urease and phosphatase, as an indicator of soil contamination of heavy metals [47,48,49,50]. They found that urease activity of agricultural soil investigated was negatively influenced by Zn, Ni and Fe. [51] demonstrated that contamination with PAHs and alkenes inhibited the dehydrogenase and urease activity in several soils.

Soil respiration rate is easy in measure and appears to be a sensitive measurement with which to detect heavy metal pollution; especially under standardized condition before treatment application, SIR was found to be between 2.17 to q.98 ML CO_2 kg^{-1} 24h^{-1} meander soil 2.05 to 1.65 ML CO_2 kg^{-1} Fadama soil in soil amended with drilling wastes SIR was stable until the 42nd day of incubation when started to decreased dependence on the treatment dosage. This can be found in Figs. 9, 10 and 11 above SIR that is a result of soil microbial activity and soil organic matter application dosage. SIR decreases especially in higher rate doses during the incubation period. This may be as a result of the inhibition of general-purpose microorganisms in the soil [52]. It was also found that SIR has a positive correlation with urease activities [53]. This phenomenon confirms the fact that SIR can be taken as the measurement of the biomass of active microbes [28].
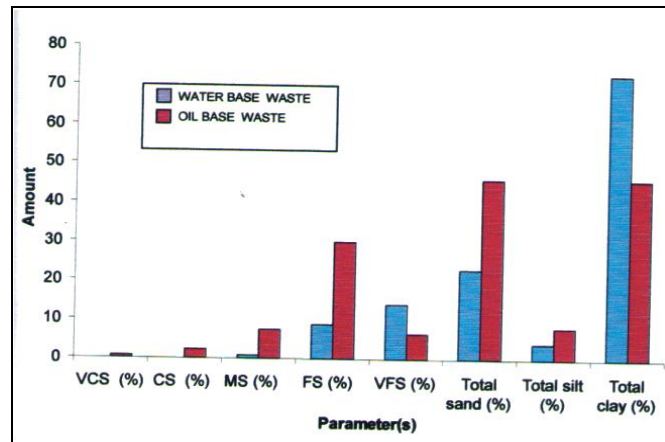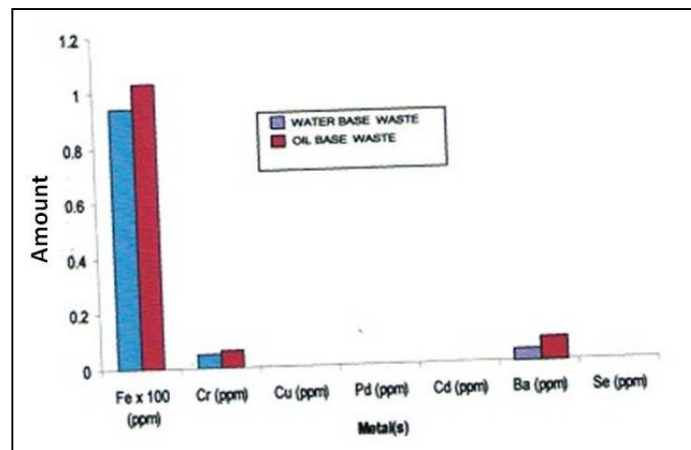

Fig. 4. Particles size of drilling waste
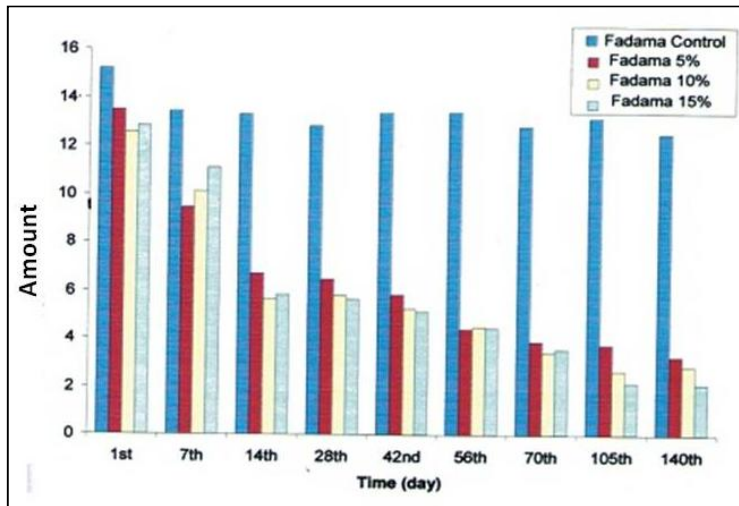

Fig. 5. Metal content in drilling waste

Fig. 6. Change in Urease activity in amended soil with drilling waste

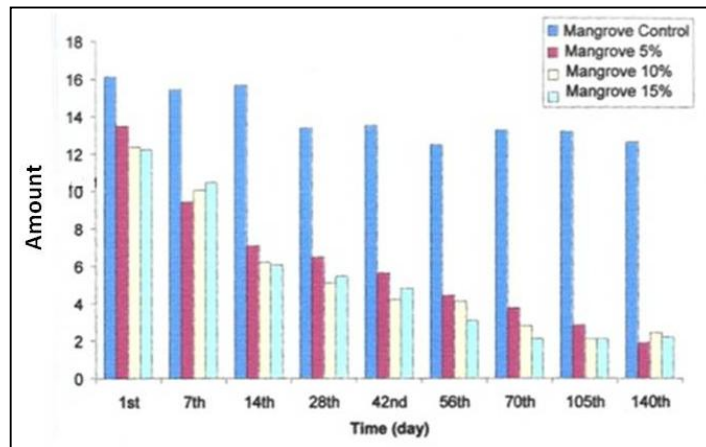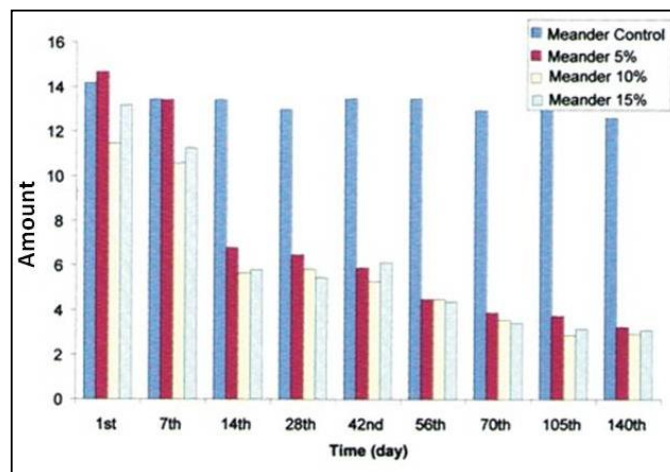**Fig. 7. Change in Urease activity in amended soil with drilling waste**

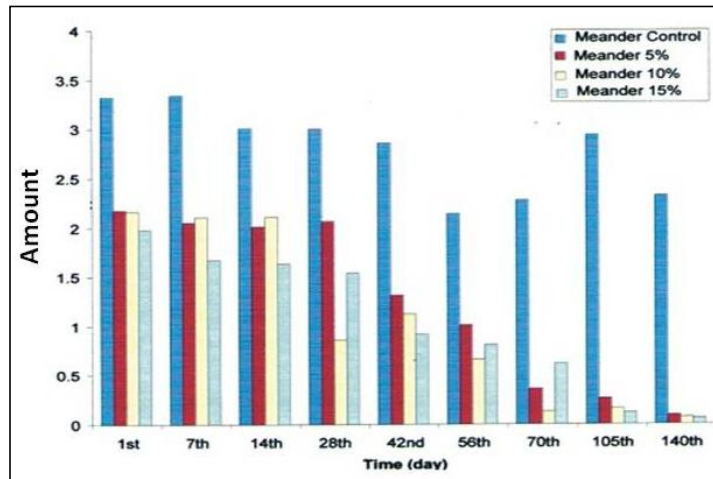**Fig. 8. Change in Urease activity in amended soil with drilling waste**

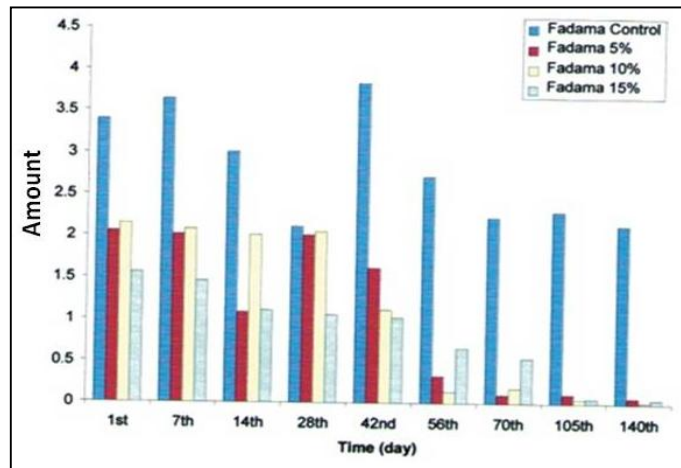**Fig. 9. Change in SIR in amended soil with drilling waste**

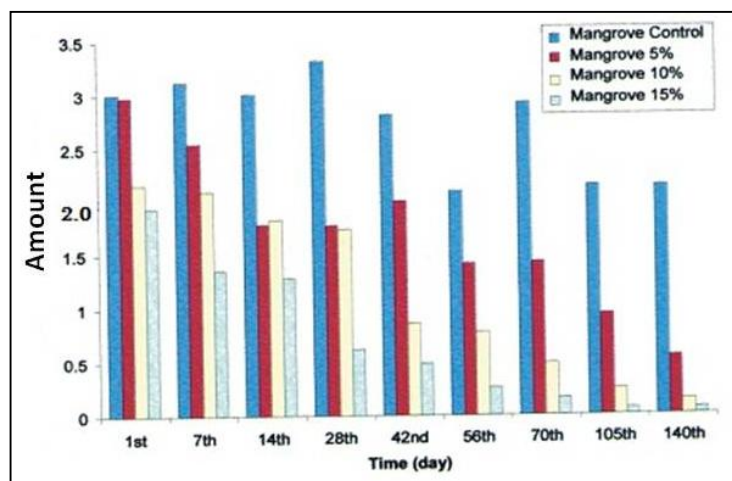**Fig. 10. Change in SIR in amended soil with drilling waste**

Fig. 11. Change in SIR in amended soil with drilling waste

4. CONCLUSION AND RECOMMENDATION

One of the main limitations in the interpretation of soil properties assessments including enzyme activities is that it is not possible to generalize the results obtained with a particular group of soils to another group of soils differing for their properties and characteristics. For this reason, the investigations here reported were deliberately performed on completely different soil types to find, if any, some relationship applicable to a more general level.

Although restricted to a limited number of soils, some of the results seem to be encouraging. For instance, urease activities and SIR were seriously affected when treated with drilling waste, thus suggesting that the enzyme urease and SIR could be proposed as sensitive indictors in soil polluted with drilling waste. The overall results have demonstrated that direct correlations can be derived between urease activity and SIR and also between different treatment levels.

The shortcoming of soil enzyme activities to be used as soil quality indicator may rely on the fact that investigations are usually performed under laboratory conditions and not in-situ, and as such, they are affected by the methodologies used for evaluating and assaying their enzyme activity levels. The available methodologies do not discriminate either among the various components contributing to the overall enzymatic activity of soil nor between enzyme and enzyme-like activities. Moreover, they often do not apply to soils that are so different from each other that it is difficult to handle them in the same way.

In conclusion, the use of soil enzyme activities as a sensitive warning of soil functioning is still problematic. Indeed, it is particularly difficult to explain a change of soil enzymatic activity in response to a certain factor or to establish the cause-effect relationship between the applied disturb and the soil enzyme activity variation. Also, the reagents for the assay of soil enzyme activities are so difficult to find that it makes it so hard and discouraging studying soil enzyme activities.

Finally, because of the importance of soil in our life, the government should encourage the research in soil chemistry by giving grants to people in that field or discipline and also make available reagents for the study of soil to a higher institution of learning across the federation.

DISCLAIMER

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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