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Assessing the Environmental Impact of Oil Spillage on Soil in Nigeria, using NNPC Depot as a Case Study

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Abstract:- The sustainability of environment depends largely on the sustainable soil ecosystem as soil is taken as a key component of natural ecosystems. Soil contamination has been an environmental problem that is facing the whole regions of the world. The source of contamination may be either natural or anthropogenic.

This research assessed the impact of oil spill on soil in Nigeria, using NNPC Depot as a case study. Soil samples were taken from the study area at four different points at a depth of 0.5-1.0 m using hand-dug auger. These samples were collected in sterilized bags and were well labelled. The following tests were conducted on the soil samples (contaminated and uncontaminated): Particle size distribution test, Compaction test, Atterberg Limit test and Permeability test.

The particle size test revealed that the variation between the two samples (contaminated and uncontaminated) is insignificant but the presence of oil in the contaminated sample caused clod thereby making it difficult to pass through some sieve sizes. The Optimum Moisture Content (OMC) and the Maximum Dry Density (MDD) gave 11.40%, 1.98 g/cm³ and 9.50%, 1.81g/cm³ for both uncontaminated and contaminated samples respectively. Likewise, The Liquid Limits (LL) and plastic limit (Pl) gave 48 %, 33.5% and 33.6% and 14.9% for both uncontaminated and contaminated samples respectively. Also, the coefficient of permeability "k" gave 2.792 x 10^{-7} cm/s compared with the standard (soil permeability classes for Civil Engineering) falls within the impermeability limit (1 X 10^{-11} – 5 X 10^{-7})

Thus the test results revealed that the contamination of soil by crude oil in NNPC Apata influenced the properties of the soil and subsequently leads to reduction in the values obtained for the entire test that the soil sample was subjected to.

***Keywords**:- Environmental impact assessment (EIA), soil contamination, oil spills, NNPC Deport, Particle size distribution, Optimum moisture content, Maximum dry density, plastic limit, liquid limit and permeability.*

I. INTRODUCTION

Environmental impact is described as a process by which information about environmental effects of a project is collected, both by the developer and from other sources, and taken into account by the relevant decision making body before a decision is given on whether the decision should go ahead (Kominkova D., 2016). It is a formal process used to predict the environmental consequences of a proposal or decision to introduce legislation, to implement policies and plans, or to undertake development projects (Barry, 2005). Soil is seeing and taken as a key component of natural ecosystems because sustainability of environment depends largely on the sustainable soil ecosystem (Adriano D.C., 2001), therefore of important is its functionality in the balance of nature.

Crude oil is one of the most common soil contaminants. Over two million tons of oil are produced all over the world every day, and about 10 percent is entering the environment due to pipeline breaks, leakage from reservoir tanks, tanker accidents, discharge from coastal facilities, and offshore petroleum productions. Several hydrocarbon components in crude oil are toxic and have a certain degree of water solubility (Dunnet G.M., 2004).

Oil contamination presents many hazards to wildlife, such as the poisoning of animals that are high in the food chain when they eat large amounts of other organisms that have taken oil into their tissues; the interference with breeding behaviour by making animals too ill to breed; the irritation or ulceration of the skin, mouth, or nasal cavities; damage to red blood cells; damage to the adrenal tissue of birds, which interferes with their ability to maintain their blood pressures and the concentrations of fluids in their bodies, and leads to a decrease in the thickness of egg shells. Hormonal balance alterations in birds, including changes in luteinizing protein, can also result from exposure to petroleum (Dunnet G.M., 2004).

Contamination of soil can occur through spills of fluids during drilling and fracturing processes and during transport by truck or through wastewater pipelines and failure of well casings and equipment failures and corrosion of pipes and tanks. In some regions OGPW is transferred to wastewater treatment plants (Gilmore, et al., 2014); however, facilities may be unable to remove several anthropogenic or naturally occurring compounds. This can result in their discharge,

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following treatment, to surface water and ultimately to soil (Ferrar K. J., et al., 2013)

Oil spill is the discharge of liquid petroleum hydrocarbon into the environment due to human activity; this definition is called marine oil spills (ITOPF, 2013). This include discharge of crude oil from tanker ship operations, offshore platforms, drilling rigs and wells, as well as spills of refined petroleum products, such as diesel, gasoline, heavier fuels such as bunker fuel used by large ships (Husley et.al., 2102). Oil spills have many adverse effects on the environment. However, effort on spill containment and recovery are considered to be moderately effective. Most times, oil spills requires cleanup efforts, though care is needed to resuce additional harm that can slow down recovery (Jacqueline M., 2016)

II. STUDY AREA

NNPC Oil Depot, which is the focus of this study is located at Apata catchments area in Ido Local Government, Ibadan, Oyo State, Nigeria. Apata Town lies between latitudes 60° 30 and 60° 50 N and longitudes 30° 02` and 30° 25` E, with a very close proximity to the outskirt of Abeokuta, Ogun State. It is one of the urban-rural area in Ido Local Government of Ibadan with an estimated population of about 10, 332. The NNPC segment of Apata where a depot is located is the main thrust of the current study. The Oil depot is a crude oil reserve for the whole south western Nigeria and it is managed by Ministry of Petroleum in Nigeria. The depot measures 150m^2 in size, fenced with sandcrete blocks while the floor is made of concrete slab. Normal depot operations are carried out from Monday to Sunday. Figure 1 and 2 shows the map of Ibadan and area view of NNPC oil depot.

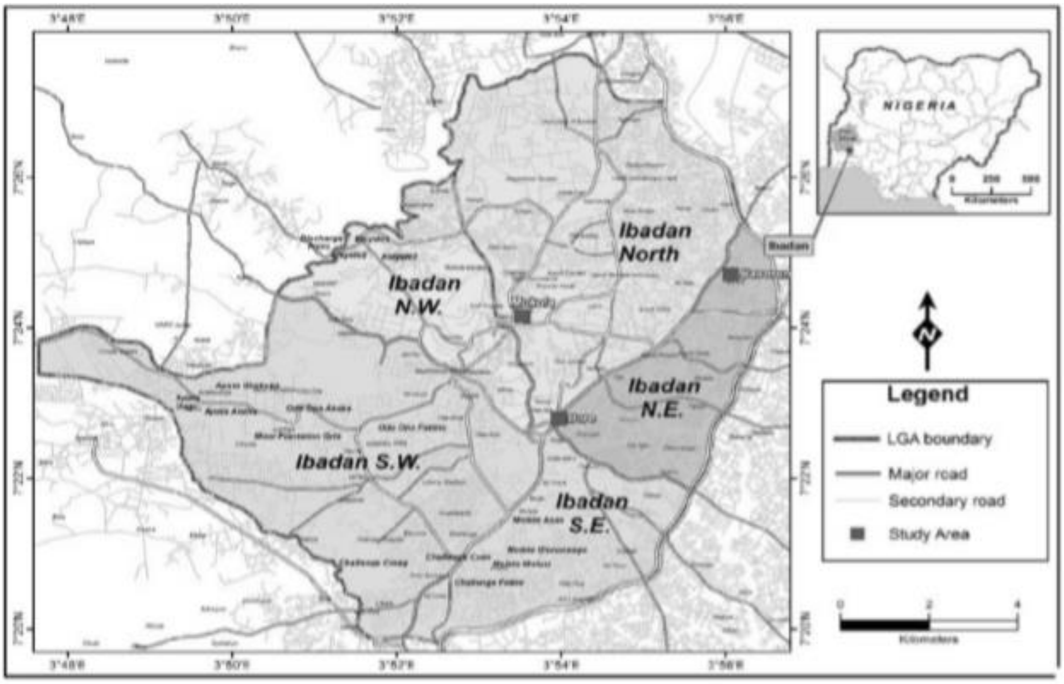

Figure 1: Map of Ibadan showing the study area (Source: Google Map, 2019)

Fig. 2: The Study area

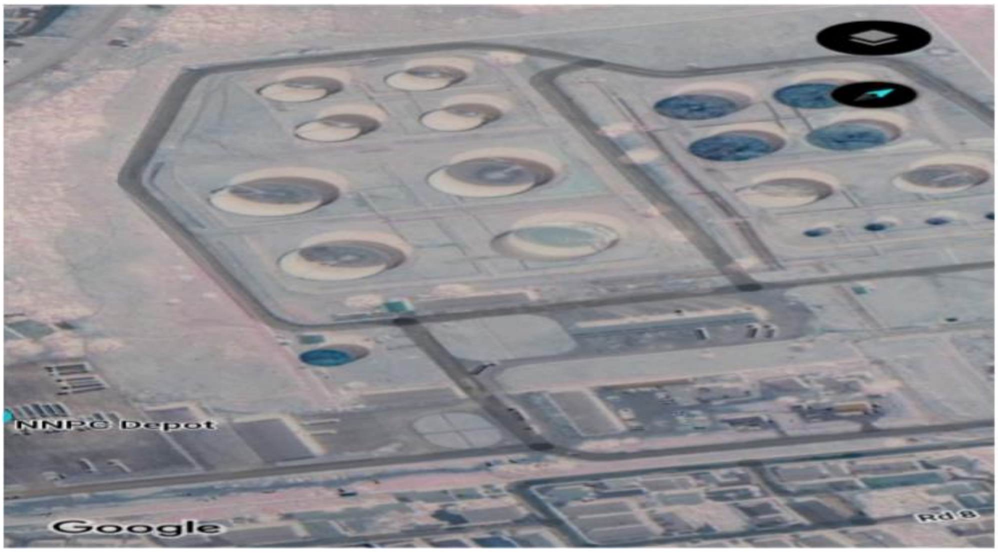

Fig. 3: area view of NNPC oil depot

A. Sample Collection

Soil samples were collected from NNPC oil depot, Apata, Ido Local Government Area. It was collected in two locations where oil spills occurs and where there was no spill. These were achieved by using hand auger at a depth of 0.5-1.0 m for both locations. Samples were collected from four sampling points. The samples were labeled and taken to Soil Laboratory at the Department of Civil Engineering, University of Ibadan where they are oven dried.

B. Methodology

A total of 4 sampling points for soil were identified, soil samples were collected using a hand dug soil auger at depth within 0.5-1.0 m and were then put in sterilized bags and labeled before finally taken to the laboratory for analysis. The following test was conducted on the soil samples:

- Particle size distribution test for both contaminated and uncontaminated soil.
- Compaction test for both contaminated and uncontaminated soil.
- Atterberg Limit test to determine the plastic and liquid limit of both samples.
- Permeability test for contaminated soil and it was compared with standard.

III. RESULT AND DISCUSSIONS

- **Particle Size Distribution Test**

Particle size distribution test was carried out on the soil samples collected. The soil collected was reddish brown and obtained from a borrow pit at Apata, Ibadan, Nigeria. The soil had a large amount of kaolinite clay mineral and 87% silt. Various concentrations of the oil (1, 2, 3, 4, 5 and 6% oil content) were mixed with the dry soil sample. The oil contaminated soil was passed through 2.4 to 0.075mm sieve sizes and percentage of soil that passed through each sieve was determined to get the aggregate size distribution. Fig 1 shows the aggregate size distribution curves of the contaminated and uncontaminated soils. The aggregate size distribution curve shifted from finer to coarser as oil contamination increased from 0 to 6% by dry weight of the soil.

PARTICLE SIZE DISTRIBUTION				
UNCONTAMINATED SAMPLE				
INITIAL WT	758.22			
SIEVE SIZE (MM)	WT RETAIN	% RETAIN	CUM %	% FINER
3.35				100
2.36	0.35	0.05	0.05	99.50
1.70	0.20	0.03	0.08	99.92
1.18	0.20	0.03	0.11	99.89
0.60	0.60	0.08	0.19	99.81
0.50	0.35	0.05	0.24	99.76
0.40	1.00	0.13	0.37	99.63
0.25	205.15	27.06	27.43	72.57
0.15	441.35	58.21	85.64	14.36
0.75	89	11.74	97.38	2.62
PAN	8.6	1.13	98.51	1.49
	746.8			

Table 1: Particle Size Distribution Test for Uncontaminated Soil

PARTICLE SIZE DISTRIBUTION				
SAMPLE DESCRIPTION		8% CONTAMINATION		
INITIAL WT	840.2			
SIEVE SIZE (MM)	WT RETAIN	% RETAIN	CUM %	% FINER
3.35	0	0	0	100
2.36	10.6	1.20	1.20	98.8
1.70	6.05	0.72	1.92	98.08
1.18	5.70	0.68	2.60	97.4
0.60	8.55	1.02	3.62	96.38
0.50	1.70	0.20	3.82	96.18
0.40	4.65	0.55	4.37	95.63
0.25	38.6	4.59	8.96	91.04
0.15	445.4	53.01	61.97	38.03
0.75	300.7	25.79	97.76	2.24
PAN	10.55	1.26	99.02	0.98
	831.96			

Table 2: Particle Size Distribution Test for Contaminated Soil

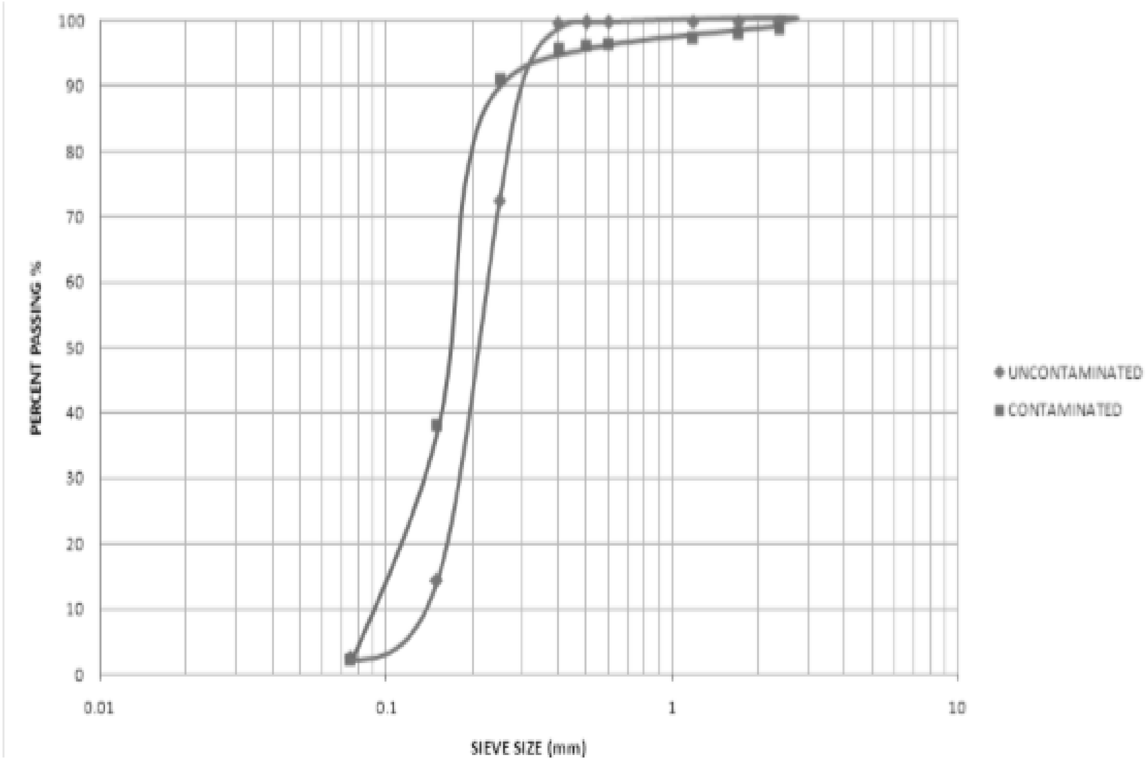

Fig. 4: Particle size distribution curve for both contaminated and uncontaminated soil samples

- **Discussion:** Fig. 4 shows the particle size distribution of both samples. Though the variation was not really much but it was due to the oil which clod different particles and prevents them from successfully passing through each stack of sieve. It is therefore necessary to properly analyze soils of this kind to avoid false value being use.

- **Compaction Test**
  5000g of oven dried soil mixture was contaminated with oil and separated for each test. A known amount of water was added and manually mixed into the contaminated soil. The soil mixture that contained oil and water was kept in a container for 24 hours. The compaction test for each soil mixture was carried out. Known water contents were measured incrementally and added into the soil.

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COMPACTION-TEST

TESTED BY:							DATE:					
SAMPLE LOCATION: NNPC OIL DEPOT APATE							MOULD VOL(CM^3): 2316.97					
NO OF BLOWS:27							NO OF LAYERS:3					
WEIGHT OF RAMMER:4.5KG							MOULD WEIGHT(g):2750					
SAMPLE DESCRIPTION: UNCONTAMINATED												
DETERMINATION NO	1		2		3		4		5		6	
WT OF WET SOIL + MOULD(g)	6700		6850		7100		7250		7350		7250	
WT OF WET SOIL (g)	3950		4100		4350		4500		4500		4500	
WET DENSITY p(g/cm^2)	1.7		1.72		1.88		1.94		1.99		1.94	
DRY DENSITY p$_d$(g/cm^2)	1.62		1.67		1.74		1.79		1.80		1.76	
MOISTURE CONTENT												
LID NO	Ab	Ah	5a	Soq	AF	A1	AC	Aq	Ba	Bb	fb	B2
WT OF LID(g)	41.75	41.80	41.45	41.75	41.65	41.80	41.60	41.70	41.40	41.35	41.70	41.40
WT OF WET SOIL + LID(g)	89.50	98.80	73.10	76.00	75.25	80.20	86.50	78.65	82.00	87.30	94.10	102
WT OF DRY SOIL + LID (g)	87.15	96.10	71.35	74.00	72.85	77.50	82.90	75.75	78.25	83.10	89.00	96.50
WT OF DRY SOIL(g)	45.40	54.30	29.90	32.25	31.20	35.70	41.30	34.05	36.85	41.75	47.30	55.10
WT OF WATER(g)	2.35	2.70	1.75	2.00	2.40	2.70	3.60	2.90	3.75	4.20	5.10	5.80
MOISTURE CONTENT %	5.18	4.97	5.85	6.20	7.69	7.56	8.72	8.52	10.18	10.06	10.78	10.53
AVERAGE MC %	5.07		6.03		7.63		8.62		10.12		10.65	

Table 3: Compaction Test Result for Contaminated Soil

COMPACTION-TEST

TESTED BY:							DATE:					
SAMPLE LOCATION: NNPC OIL DEPOT APATE							MOULD VOL(CM^3): 2316.97					
NO OF BLOWS:27												
WEIGHT OF RAMMER:4.5KG							MOULD WEIGHT(g): 2750					
SAMPLE DESCRIPTION: UNCONTAMINATED												
DETERMINATION NO	1		2		3		4		5		6	
WT OF WET SOIL + MOULD(g)	7500		7750		7850		7850		7760		7650	
WT OF WET SOIL (g)	4750		5000		5100		5100		5010		4900	
WET DENSITY p(g/cm^2)	2.05		2.16		2.20		2.20		2.16		2.11	
DRY DENSITY p$_d$(g/cm^2)	1.89		1.98		1.98		1.95		1.89		1.93	
MOISTURE CONTENT												
LID NO	A1	Agk	Ad	900	C5	Bb	F1	110	Aq	Oo2	Bg	08
WT OF LID(g)	41.45	41.50	41.35	41.55	41.55	41.20	41.40	41.40	41.60	41.75	41.40	41.35
WT OF WET SOIL + LID(g)	85.65	85.35	87.30	94.35	87.85	90.45	101.00	101.65	92.55	83.35	93.30	92.9
WT OF DRY SOIL + LID (g)	82.30	81.80	83.65	89.80	83.25	85.55	94.25	94.90	86.25	78.20	91.50	85.8
WT OF DRY SOIL(g)	40.85	40.30	42.30	48.25	41.70	44.35	52.85	53.50	44.65	36.45	50.10	44.45
WT OF WATER(g)	3.35	3.55	3.65	4.55	4.60	4.90	6.75	6.75	6.30	5.15	1.80	7.10
MOISTURE CONTENT %	8.20	8.81	8.63	9.43	11.03	11.05	12.77	12.62	14.11	14.13	3.59	15.97
AVERAGE MC %	8.50		9.03		11.04		12.69		14..12		9.78	

Table 4: Compaction Test Result for Uncontaminated Soil

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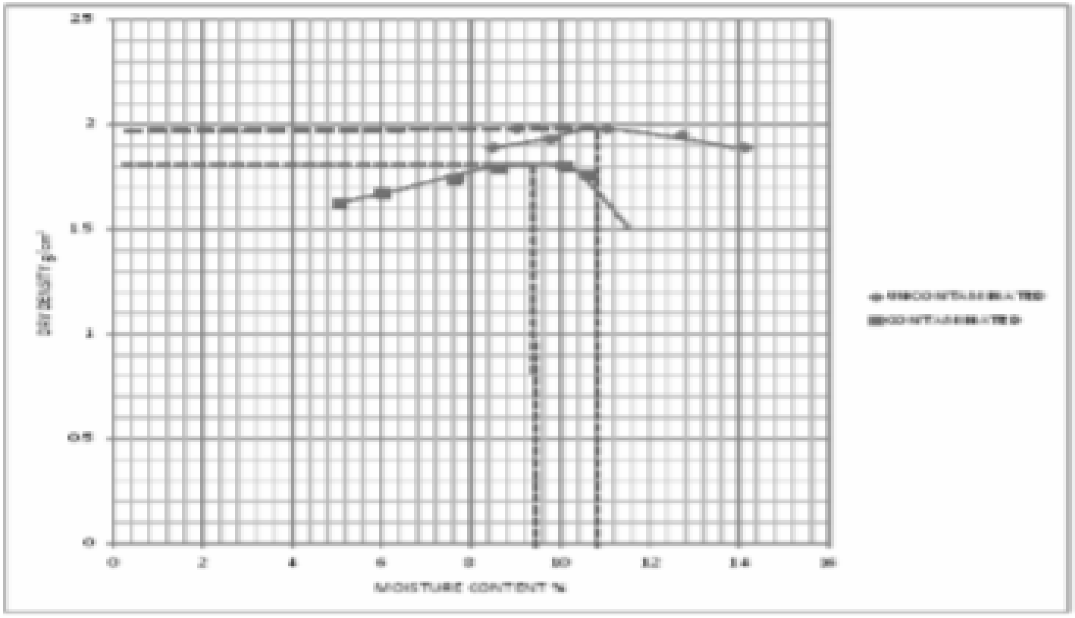

Fig. 5: Summary of compaction test for both contaminated and uncontaminated soil samples

- **Discussion:** From Fig 5, the Optimum Moisture Content (OMC) and the Maximum Dry Density (MDD) of uncontaminated soil gave 11.40%, 1.98g/cm³ and contaminated soil gave 9.50%, 1.81g/cm³ respectively. The reason for the reduction was because soil pores already contained more oil. The higher the oil contents in the soil, the lower the moisture content that would be deflocculating the contaminated soil to attain the maximum dry density

- **Atterberg Limit Test:** Atterberg limit test was performed to determine the plastic and liquid limits of both soil samples. The results obtained are presented in Table 5, 6 and Fig 3, 4.

PLASTIC LIMIT TEST					
TEST NO.	1	2	3	1	2
Container No.				AA	AB
Wet Soil & Container (gm)				27.30	29.60
Dry Soil & Container (gm)				24.90	24.40
Container Empty (gm)				14.40	14.90
Dry Soil (gm)				20.30	24.40
Loss of Water (gm)				2.40	5.20
Moisture Content %				11.82	21.31
Plastic Limit, PL %					**33.50**

Table 5: Plastic limit test result for uncontaminated soil

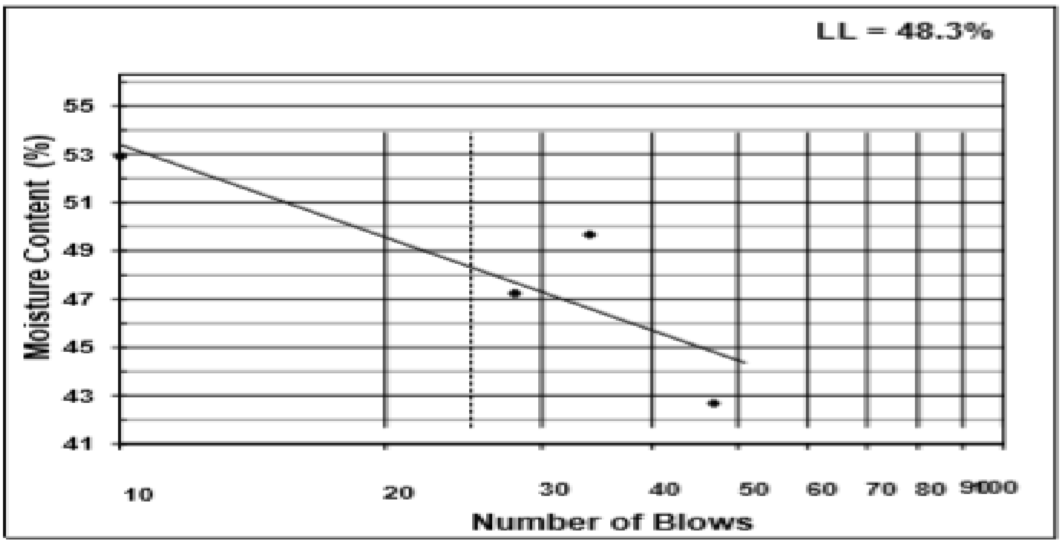

Fig 6: Liquid limit test result for uncontaminated soil

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PLASTIC LIMIT TEST					
TEST NO.	1	2	3	1	2
Container No.				A	B
Wet Soil & Container (gm)				26.70	25.60
Dry Soil & Container (gm)				24.90	24.40
Container Empty (gm)				14.40	14.90
Dry Soil (gm)				10.50	9.50
Loss of Water (gm)				1.80	1.20
Moisture Content %				17.14	12.63
Plastic Limit, PL %				**14.90**	

Table 6: Plastic limit test result for contaminated soil

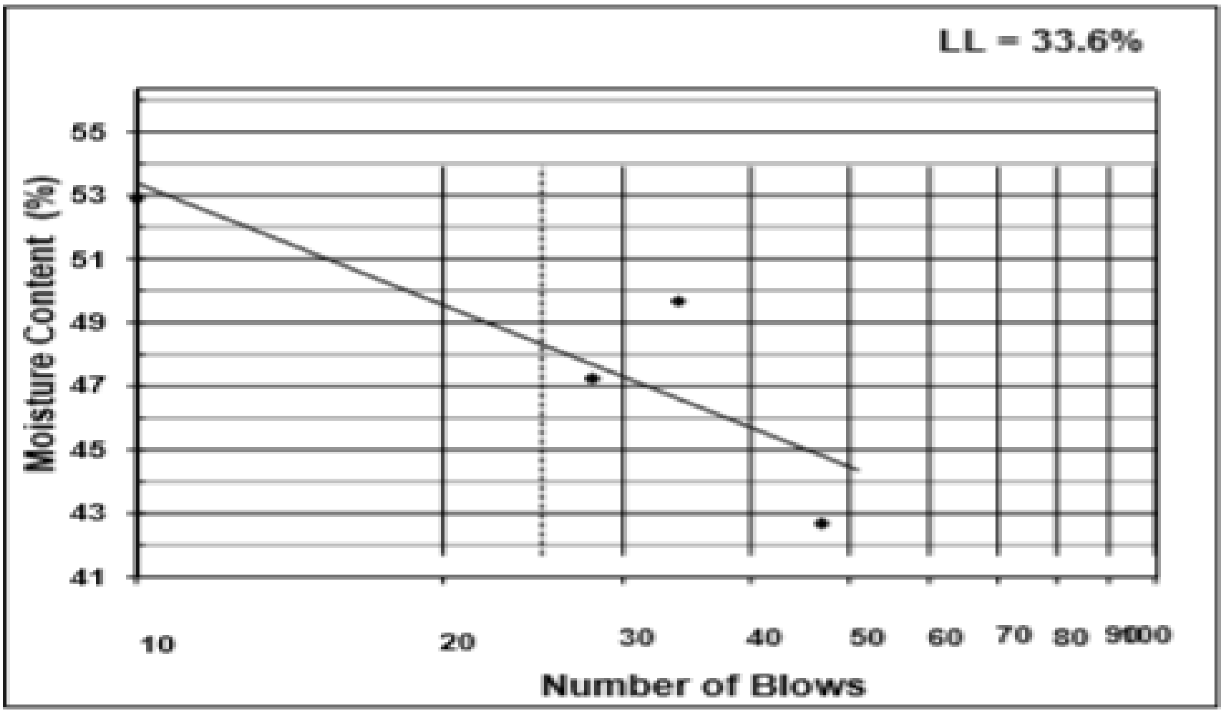

Fig. 7: Liquid limit test result for contaminated soil

- **Discussion:** The Liquid Limits (LL) and plastic limit (Pl) of the uncontaminated soil is 48 % and 33.5% respectively while that of contaminated gave 33.6% and 14.9%. The decrease in the value of LL and Pl of the contaminated soil was due to the alteration of the cohesive bonds and forces that exist between the particles of the lateritic soil. The decrease was also due to reduction in the Cation Exchange Capacity (CEC) of the soil.

- **Permeability Test**
Permeability test was also conducted on the soil samples collected. The result obtained was then compared with the soil permeability classes for Civil Engineering (standard). The result obtained was presented in Table 7 and the standard in Table 8.

PERMEABILITY TEST			
Project:	**Sample Location: NNPC Depot, Ibadan.**		
Volume of mould: 1000cm^3	**Rammer: 2.5kg**		
Layer: 3	**No. of blows/layer: 27**		
Test Number	1	2	3
Height of upper mark H1 (cm)	117.0	117.0	117.0
Height of upper mark H2 (cm)	35.0	35.0	35.0
Length of sample L (cm)	10.0	10.0	10.0
Area of sample A (cm^2)	78.6	78.6	78.6
Area of standpipe a (cm^2)	0.159	0.159	0.156
Difference in time (sec)	832.0	840.0	960.0
Co-efficient of permeability k= (2.3(a.l))/((A.t))Log h1/h2	0.0000002932	0.0000002904	0.0000002541
K average (cm/s)		0.0000002792	

Table 7: Permeability test result for the soil sample

Soil Permeability classes for Civil Engineering		
Soil Permeability classes	Coefficient of permeability (K in m/s)	
	Lower limit	Upper limit
Permeability	2 X 10^{-7}	2 X 10^{-1}
Semi- Permeability	1 X 10^{-11}	1 X 10^{-5}
Impermeability	1 X 10^{-11}	5 X 10^{-7}

Table 8: Soil permeability classes for Civil Engineering (standard)

- **Discussion:** The value of coefficient of permeability "k" of contaminated soil when compared with the standard indicated that it falls between ranges of impermeable soil and this is due to the presence oil in the soil which hinders the rate of permeability.

IV. CONCLUSSION AND RECOMMENDATIONS

The study assessed the environmental impact of oil spillage on soil in Nigeria, using NNPC Apata depot as a case study. From the experimental results, it can be concluded that the contamination of soil by crude oil in NNPC Apata affect the properties of the soil and this result in the reduction in the values obtained for all the test that the soil was subjected to.

Since the outcome of this study revealed that crude oil spills degrade lateritic soil, the following recommendations were then made:

- The use of degreaser for soil reclamation should be used to biodegrade the oil molecules.
- Mechanical method such as booms and skimmer should be used in oil contaminated area to block the spread of oil.
- Likewise, areas where contaminated oil may reach shorelines and cleanup becomes difficult, dispersing agent called dispersant may be used.
- Public enlightenment on the dangers of crude oil spills should be conducted regularly for the residents of areas prone to crude oil spill.
- Oil companies should also endeavour to improve on their exploration and exploitation process to minimize spillages.
- Besides, government should enact and implement laws to force oil companies to thoroughly clean up crude oil after each spill. This would help reduce its frequency of occurrence and minimize its effect on soil.

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