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Effect of Crude Oil on Permeability Properties of the Soil

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ABSTRACT

The impact of crude oil on the permeability of the soil in a non-oil producing community in Enugu State was investigated using disturbed A-6 (CL) soil sample collected from Ibagwa Nike area of the state. The sample was divided into five (5) portions and each of the four (4) portions was dosed with Bonny light crude oil at 2%, 4%, 6% and 8% by weight of the samples. The physical properties of the uncontaminated soil were tested and analyses and used as control. The aim of the laboratory investigation was to determine the effects of crude oil on the permeability of the soil. The permeability of the uncontaminated soil was found to be 1.2609×10^{-7}. Permeability tests were also conducted on the contaminated soil samples at the various percentage contaminations. The results showed that at 2% crude oil contamination the permeability was 9.6403×10^{-9}, a drastic reduction. The other results were 6.9600×10^{-6}, 2.2621×10^{-8} and 9.1286×10^{-8} at 4%, 6%, and 8% contamination levels, respectively. The ranking after contamination is seen to drop within the range of 10^{-8} and 10^{-9} showing a change in the permeability due to oil content. This observed reduction in permeability alters the natural groundwater recharge which can be remedied by enhanced bioremediation through aeration of the soil.

Keywords: *Contamination, Crude oil, Groundwater, Permeability, Silty clay soil*

1. INTRODUCTION

During oil activities, a wide range of environmental hazards is created on the aquatic, terrestrial as well as the atmospheric environments. When crude oil is spilled, the soil takes a huge chunk of it; some will flow into water bodies while the others evaporate into the atmosphere. Contamination of the soil through any means is a major challenge to the environmentalists, geotechnical and civil engineers, agricultural scientists as well as architects who depend on the soil's load bearing value for maximum support to their buildings. Crude oil has been implicated as a major source of contamination resulting in building failures due to the reduction in some geotechnical properties of the contaminated soil especially in the oil rich communities in the Niger Delta areas of Nigeria. According to Nudelman, Rios and Katusich (2002), crude oil pollution on land depends on a number of factors which include: the permeability of the soil, adsorption properties of the soil and the partition coefficient, while Fine, Graber and Yaron (1997) opined that the extent of contamination depends on the chemical composition of the contaminant and the properties of the soil.

When crude oil spills, natural see page of the hydrocarbon, by gravity, takes place, thus polluting the soil, and the extent and depth of penetration depend largely on the viscosity and quantity of the oil, temperature and characteristic properties of the soil. The physical as well as the chemical properties of the soil in contact with the oil are immediately altered. As posited by Tuncan and Pamukcu (1992), once a spill or a leakage occurs, the hydrocarbon liquid, under gravity, moves down to the groundwater, partially saturating the soil in its pathway. As the oil is moving vertically down there is equally a horizontal spread thus increasing the pollution coverage? The soil, water and air in the Niger Delta areas of Nigeria have been violently polluted and the communities copiously devastated as a result of intensive oil activities and extensive oil spillage within the area for over 60 years now.

While these activities were going on, a litany of oil spills have been reported and recorded. Several tons of oil is thus thrown into the environment. As stated

by Kontagora (1991), estimated total quantities of 2,105,393 barrels of oil were spilled on land, coastal and offshore marine environments. This was as at the time of recording. Report by some oil companies in Nigeria showed that between 1976 and 1990, a total of 2,796 oil spill incidents took place across the oil rich Niger Delta areas of Nigeria. The magnitude of crude oil pollution and damage caused/triggered by multi-national oil companies' operation in the Niger Delta of Nigeria have precipitated a slow poisoning of waters in the region, destruction of vegetation and agricultural land which occur during oil spill, Iyimdiya (2010a, b and 2013); Marr and Hooper (1998); Corbett (2004); Sahel (2007).

This oil spill phenomenon is not without obvious causes which include but not limited to: dilapidated oil infrastructure, operational errors, sabotage, oil bunkering, and willful damage of oil infrastructure by competing groups of rebels and agitators, faulty well heads, accidental discharge, and transportation problems. These causes were collaborated by Francesca (1998) as the author enumerated the causes to include: corrosion of pipelines and tankers (accounting for 50% of all spills), sabotage (28%), oil production operations (21%), inadequate or non-functional production equipment (1%).

Crude oil has been implicated as a major source of contamination resulting in building failure due to the reduction in some critical geotechnical properties of the contaminated soil in the oil rich communities in the Niger Delta areas of Nigeria. As observed by Akinwumi, Diwa and Obianigwe (2014), the change in the engineering properties and behavior of soils due to crude oil contamination, has far-reaching implication on existing and proposed structure to be supported by such soil. It can result in structural or functional failure of existing structures, especially when the contamination causes a significant increase its settlement, and/or prevent drainage of water or other liquid, they further opined. This according to them could result in overall increase in construction cost or outright abandonment of the contaminated site.

Elsewhere, around the globe, researchers have carried out extensive and intensive studies on the effects of crude oil pollution of soils on the engineering properties of the soil. Olgun and Yildiz (2010) studied the effects of methanol, ethanol, isopropyl alcohol and acetic acid on the plasticity, consolidation and shear strength of contaminated clay soil. Khamehchiyan, Charkhabi and Tajik (2007) studied the effects of crude oil contamination on geotechnical properties of clayey and sandy soils, while Kermani and Ebadi (2012) investigated its effects on the plasticity and compaction characteristics of fine-grained soils. Oyegbile and Ayininuola (2013) carried out their study on the effect of crude oil contamination of lateritic soil on its shear strength, while Akinwumi, Diwa and Obianigwe (2014) investigated the effects of crude oil contamination on the index properties, strength and permeability of lateritic clay. Other researchers include: Ewetola (2013); Ayininuola and Kwashima (2015); Otunyo (2010); Jesna and Hari (2015); Nazir (2011). The dissimilarities observed in some of the results make generalization difficult especially on clay soils, and may be attributed to several factors some of which are: chemical and physical properties of the crude oil and the soil. This study, therefore, provides additional literature on the effects of crude oil on the permeability properties of the soil in a non-oil producing area of Nigeria.

2. MATERIALS AND METHODS

2.1. Sample Collection and Preparation

Ibagwa Nike, Enugu East Local Government Area of Enugu State is not an oil producing community but their basic economic activity is anchored on land speculation. They place premium on land and the soil sample was collected from this community. A disturbed sample was collected at depth of 0.6m and put in a polythene bag, sealed and transported to the laboratory for the requisite tests and analyses. The Bonny light crude oil was used as the contaminant.

2.2. Methods

The sieved sample was moisturized at OMC and allowed to stay for 24 hours. It was then divided into five (5) parts and crude oil was added to each part in 0%,2%, 4%, 6%, and 8% proportions by weight of the sample, respectively. The soil and oil in each part were mixed thoroughly and allowed to cure for five (5) days before commencement of the tests. Consolidation parameters were used to compute the permeability results and the method were in accordance with BS 1377.The cured sample was remolded for the test and loads were applied in stages and allowed to stay in the machine for 24 hours. Readings were taken accordingly. Thereafter, the sample and the consolidation ring were weighed and

dried in the oven at temperature range of 105^0C and 110^0C for 48 hours. The dry weights were recorded.

3. RESULTS AND DISCUSSIONS

The natural properties of the soil sample are as presented in table 1. The percentage passing BS-No200 sieve is 90%. The Liquid Limit, Plastic Limit, and Plasticity Index are 32%, 19%, 13% respectively, while the Specific Gravity and Natural Moisture Content are 2.63 and 8.2% respectively. The soil is classified as A-6 (CL) soil using AASHTO and USCS classification systems respectively. This is shown in the soil test summary, in table 2.

Table 1: Natural Properties of the Soil

S/NO	Properties	Values
1	Percentage passing B.S N0 200 sieve	90
2	Liquid Limit (LL)	32%
3	Plastic Limit (PL)	19%
4	Plasticity Index (PI)	13%
5	AASHTO Classification	A-6
6	USCS	CL
7	Specific Gravity (SG)	2.63
8	Natural Moisture Content (NMC)	8.2

Table 2: Soil Test Summary

Location	Depth M	Atterberg limits			Percentage Passing B.S Sieves								AASHTO Compaction	Classification
		LL	PL	PI	4.76	7	14	25	35	52	100	200	G.S.	
Ibagwa Nike	0.6	32	19	14	97	94	94	93	93	92	92	90	2.26	A-6 (CL)

Key:Ibeagwa Nike; CL =Silty Clays

The results of the permeability at the various contamination levels are as shown in table 3.

Table 3: Effect of Crude Oil on Permeability

0% Oil (cm^2/sec)	2% Oil (cm^2/sec)	4% Oil (cm^2/sec)	6% Oil (cm^2/sec)	8% Oil (cm^2/sec)
1.2609×10^{-7}	9.6403×10^{-9}	6.9600×10^{-9}	2.2621×10^{-8}	9.1286×10^{-8}

For the uncontaminated soil sample the permeability is 1.2609x10-7 indicating silty clay. When contaminated with 2%, 4%, 6% and 8% crude oil by weight of soil the results were $9.6403x10^{-9}$, $6.9600x10^{-9}$, $2.2621x10^{-8}$ and $9.1286x10^{-9}$ respectively.

The ranking after contamination ranges from 10^{-8} to 10^{-9} showing a change in the permeability property of the soil from silty clay to clayey soil sample, thus making the soil sample more impermeable. At 0% contamination, the permeability result showed that the soil sample is porous enough to allow infiltration and

flow of oil into the soil through the voids between the soil particles. The oil contamination induced a reduction in permeability of the samples. This is in line with the findings of Ayininuola*et al*(2015).Also Khamehchiyan*et al*(2007) obtained similar result in their study of the effect of crude oil on geotechnical properties of coastal soils. Similar results were equally obtained in Rahman, and Umar Ahmad (2010), and Sharma (2014).

This reduction in permeability hinders the flow of water in the soil which invariably affects the groundwater levels. Groundwater is the major source of municipal water and makes up about 20% of the World's fresh water (Ludwig, Hilborn, Walters, 1993). Groundwater generally feeds from surface water through precipitation from rivers, streams and the rains. When the natural recharge rate of groundwater is impeded or hindered, as is done when there is reduction in permeability of the soil, the groundwater will be drastically reduced and if water is constantly being drawn from boreholes within the vicinity of spill area, there will be depletion in groundwater level due to continuous use and sometimes overuse. This can cause major fundamental problems both to human and the environment. The mostevident problems are lowering of water table, subsidence and salt water intrusion, Ayininuola*et al* (2015). When the soil particles are coated with oil, the tend to stick to themselves, literally blocking the passage of water. As a result of crude oil pollution, soil physical properties such as pore spaces might be clogged, which reduces soil aeration, infiltration of water into the soil, increased bulk density of the soil which may affect plant growth (Abosede, 2013)

CONCLUSION:

The result of the physical properties of the soil used for the study showed and A-6 (CL) soil which is a silty clay soil. When contaminated with crude oil, the permeability of the soil was reduced sufficiently enough to create some concerns. The natural recharge of the groundwater is impeded resulting in drastic deficiency and reduction in the groundwater level which can create significant environmental problems. Bioremediation is therefore recommended for such areas of spill. Also the natural recharge of groundwater can be enhanced by sufficiently aerating the contaminated soil and directly exposing it to sunlight to improve its permeability and subsequently the infiltration potentials of the soil and as well enhance bioremediation processes and results.

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