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EFFECT OF PETROLEUM POLLUTION ON CLAYSOIL GEOTECHNICAL PROPERTIES OF ABEOKUTA, NIGERIA

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Abstract: Petroleum is of great economic benefit to any nation. Most emphasis on petroleum contamination on the environment has been on surface and ground water pollution with little or no attention paid to the engineering properties of the contaminated soil. This research is thus aimed at investigating the effect of petroleum pollution on the geotechnical properties of clay soil. The contaminated soil was prepared by adding different percentages of petroleum contaminations (4%, 8% and 12%) measured by weight of the dry soil sample and mixed until a uniform mixture was obtained. The mixture was then placed in an air tight container for two months to allow for a homogeneous mixture. The classification results showed that petroleum contamination caused an increase in liquid limit, plastic limit and plasticity index between 0% to 12% contaminations. The compaction result showed that there was an increase in maximum dry density while the optimum moisture content decreased between 0% and 12% of petroleum contamination. The result also showed that the soil could not compact at 12% contamination and above. Although petroleum altered the geotechnical properties of the clay soil and reduced its strength, the soil can still be used for geotechnical purpose after remediation.
Keywords: petroleum, Clay soil, Contamination, Geotechnical properties

1. INTRODUCTION

Petroleum (Crude oil) is of significant economic importance to the development of any nation in terms of energy generation, employment and as a source of raw materials for petrochemical industries. Petroleum and its products constitute one of the most prevalent sources of environmental pollution which can occur during exploration, exploitation, production and transportation as spillage.

Oil spill is an unintentional release of liquid petroleum into the environment as a result of human activities or natural occurrence. They are usually caused by accidents involving oil tankers, barges, refineries, pipelines and oil storage facilities. Most of the petroleum spillages are accidental, although there are some known cases where petroleum was spilled purposely, for instance pipeline vandalism. Based on the grain-size distribution, the most sensitive environments to the contamination are clay soils.

The change in the properties of soil which is as a result of pollution is of major interest to Engineers and Scientists. Soil saturation by fluids which has physico-chemical properties other than that of water has been found to have a deteriorating effect on the geotechnical, mechanical properties, filtration and plasticity of the soil. The aim of this research is to investigate the influence of petroleum pollution on claysoil geotechnical properties.

2. MATERIALS AND METHOD

— Study area

The clay soil used in this study was obtained at a depth of 2m from a borrow pit, along Mawuko road, FUNAAB, Abeokuta, Ogun State, South -western Nigeria between latitude 7.22^{o}N and Longitude 3.42^{o}E.

— Sampling and analysis

The sample was collected in sacks while some were stored in a water-tight container for laboratory determination of their natural moisture content. The sample to be used for natural optimum moisture content was air-dried, passed through a 4.75 mm sieve and thoroughly mixed.

The contamination of the soil with varying types of Petroleum products (Petrol, Kerosene and spent Engine oil) was done in the laboratory.

The petroleum products were added to the soil sample by percentage contamination by mass of 0%, 4%, 8% and 12%. The mixing of the petroleum with the dry soil sample was done by hand and the mixed samples were then stored in a plastic container with the lid covered with a cellophane bag, this was to allow for proper mixing so as to attain a homogenous mixture. The cellophane bag also prevented the evaporation of the petroleum within the incubation period. Sieve analysis was carried out on the uncontaminated soil samples. Specific gravity, Atterberg limits, compaction were conducted on the uncontaminated (0% petroleum content) and contaminated soil samples, respectively. Also small incremental percentage was chosen to examine how small a contamination could be to cause a change in the geotechnical properties of a soil.

The following laboratory tests were carried out on the soil sample (contaminated and uncontaminated samples); particle size distribution, moisture content, specific gravity Atterberg (liquid and plastic limit) and compaction test.

— **Liquid Limit test procedure**

In this method, the soil paste is placed into a circular metal brass cup (casagrande apparatus) and a groove of about 2mm wide is made down its centre to separate it into two halves. The cup is then lifted and allowed to drop onto a hard rubber base. The number of such blows to cause the two soil halves to come together over a distance of 13mm is recorded and soil sample is taken to determine the moisture content of the soil. The test is repeated and a graph of moisture content versus number of blows is plotted. The flow of the two halves towards each other is related to the moisture content of the soil and the liquid limit is defined as the moisture content when the condition is achieved after 25 blows.

— **Plastic limit test procedure**

To test for the plastic limit of contaminated soil, a stiff soil paste was prepared in the same manner as in the liquid limit test. The soil was spread over a glass plate and divided into two. Also one part was further divided into four parts and small quantity was rolled in the palm to produce a uniform thread about 3mm diameter without crumbling. The crumbs were collected and placed in a moisture content container. Each of the remaining three parts of the soil portion was subjected to the same process and the average moisture content of the soil crumbs was determined. The process was repeated for the second soil portion.

— **Plasticity Index procedure**

The plasticity index of a soil is the numerical difference between the liquid limit and the plastic limit, and it is a dimensionless number (i.e. PI = LL-PL). Both the liquid and plastic limits are based on moisture contents. Hence the plasticity index for the uncontaminated soil was determined based on liquid limit and plastic limit of the uncontaminated soil.

— **Compaction test procedure**

A quantity of 4kg of oven dried soil sample was mixed in a large mixing pan. The soil was placed in mould such that it occupied a little over one third of the mould height after compaction. 25 blow were applied from the 4.5kg rammer dropped from a height of 450mm distributing blows uniformly over the surface ensuring that the rammer fell freely.

Some quantity were giving blows as stated above the third layer was also added giving 25 blows from 450mm of a 4.5kg rammer. The extension was removed, the excess soil was struck off and the surface of the compacted soil was levelled using the straight edge. The soil mould with base plate was weighed. Some samples were taken for determination of moisture content. The whole process was repeated with suitable increment of water and mix thoroughly into the soil.

3. RESULT DISCUSSION

Petrol, which is a product of crude oil was the first contaminant used in this study. It can be deduced that the addition of petrol to the soil resulted in an increase in the liquid limit, plastic limit and plasticity index. Also, the optimum moisture content and maximum dry unit weight decreased as the petroleum content in the soil increased. The specific gravity of the soil also reduced as the percentage of contamination increased.

Also, kerosene was the second contaminant used. It can be deduced that the addition of kerosene to the soil resulted in an increase in the liquid limit, plastic limit and plasticity index. Also, the optimum moisture content and maximum dry unit weight decreased as the kerosene content in the soil increased.

The specific gravity of the soil also reduced as the percentage of contamination increased. But this increase is lower than that of the petrol contaminated soil.

The presence of spent engine oil in soils has an obvious effect on its geotechnical properties. The Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) reduce with increase in spent engine oil content.

It also cause an increase in the Atterberg limits values with an increase in the spent engine oil content and decrease in specific gravity of the soil with increasing percentage of the spent engine oil content.

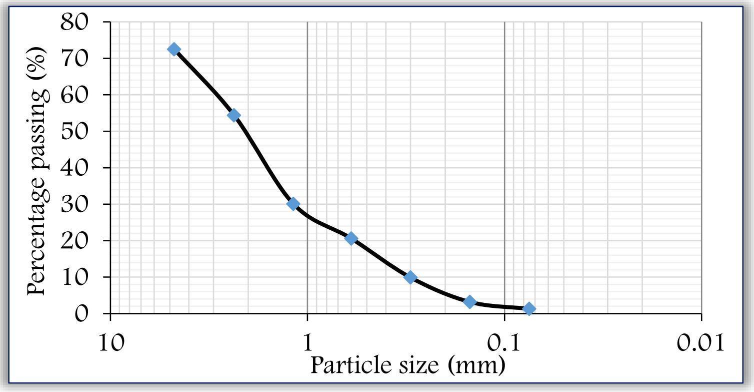

Figure 1: Gradation chart for clay soil sample

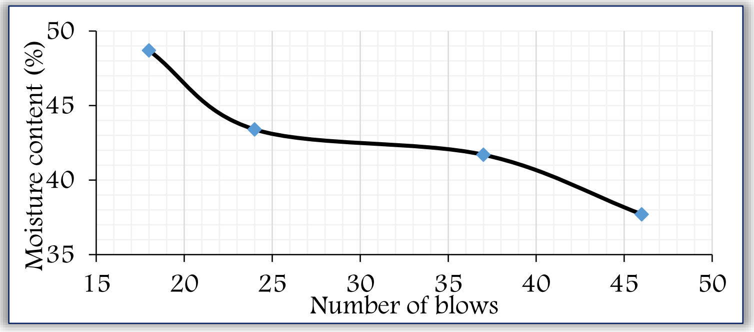

Figure 2: Liquid limit for uncontaminated clay soil sample

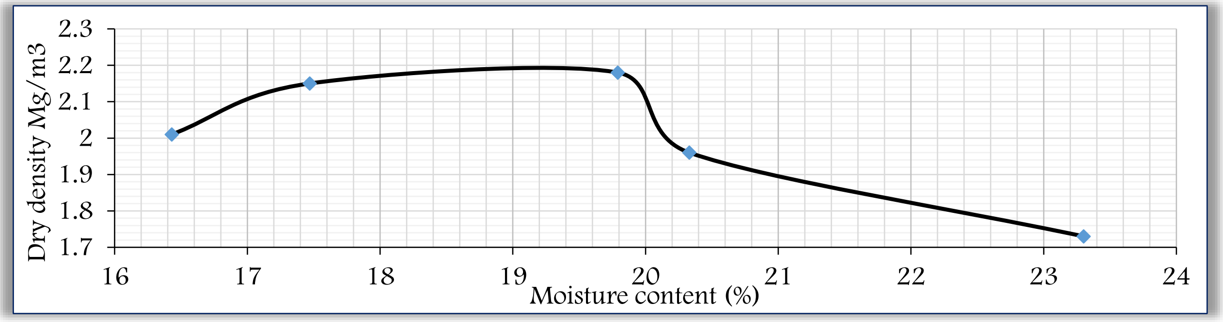

Figure 3: Moisture content against dry density of the clay soil

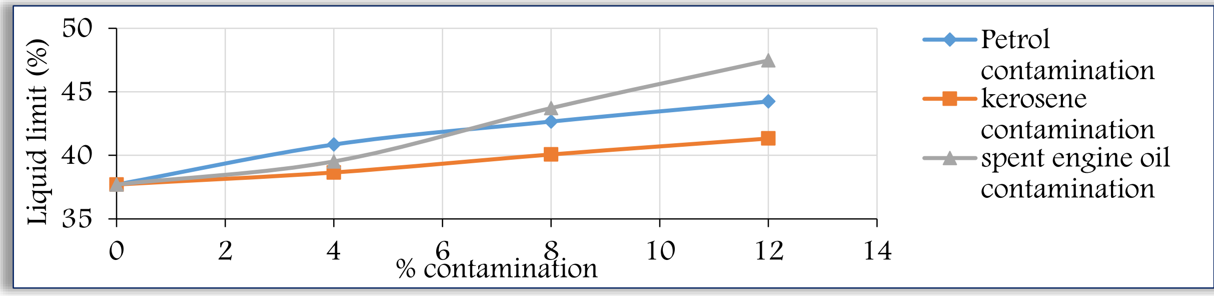

Figure 4: Liquid limit of the soil against different % contamination

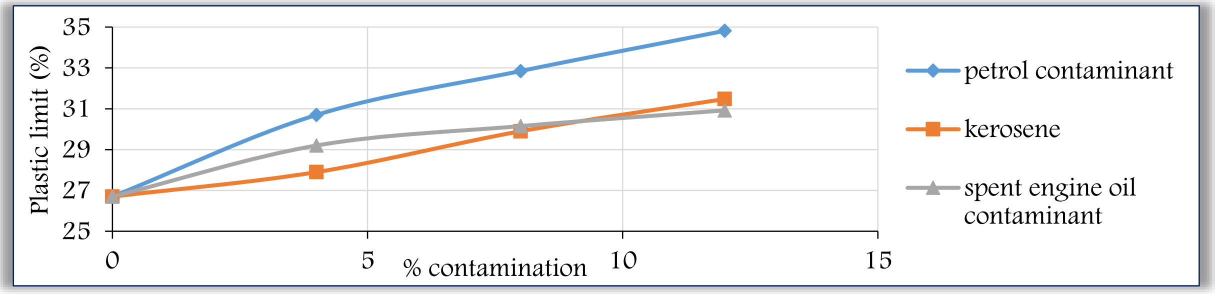

Figure 5: Plastic limit of the soil against different %contamination

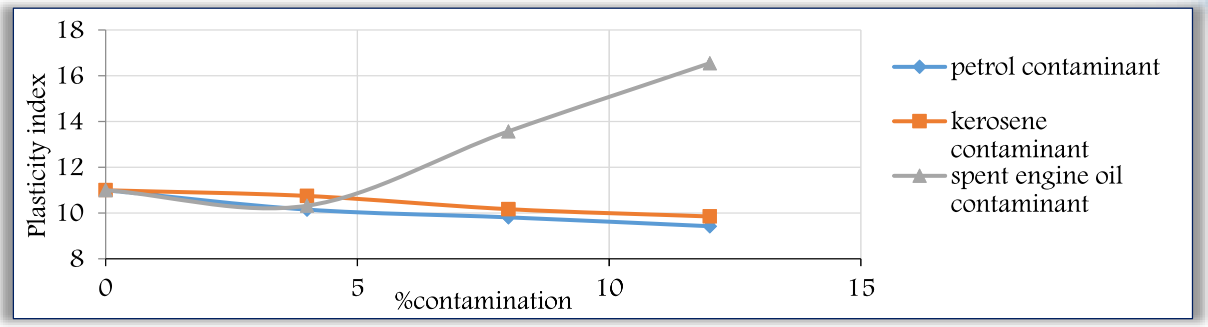

Figure 6: Plasticity index of soil against different %contamination

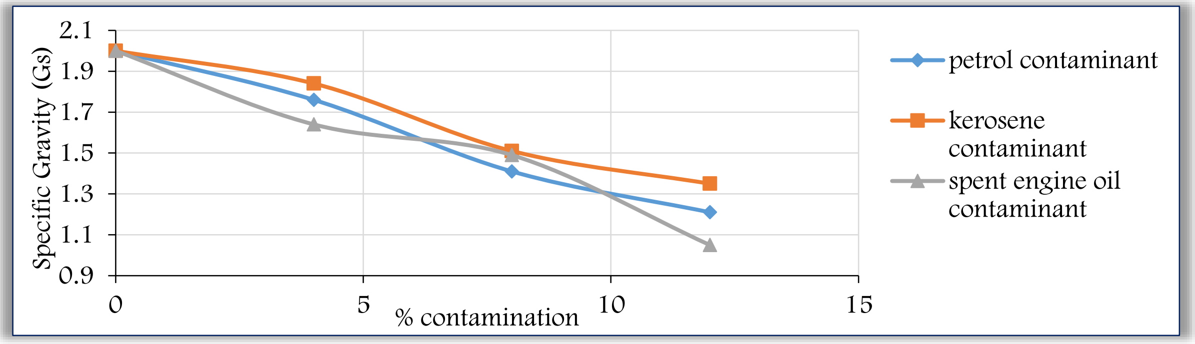

Figure 7: Specific gravity of soil against different %contamination

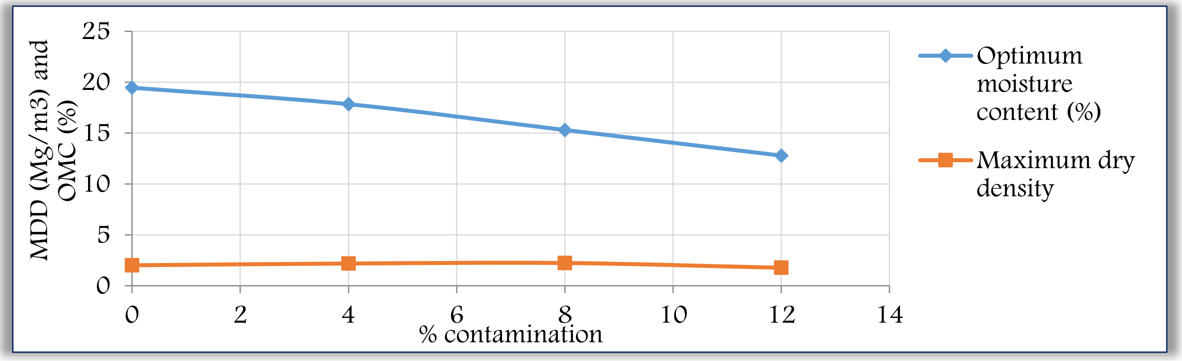

Figure 8: MC and MDD for different % contamination for petrol contamination

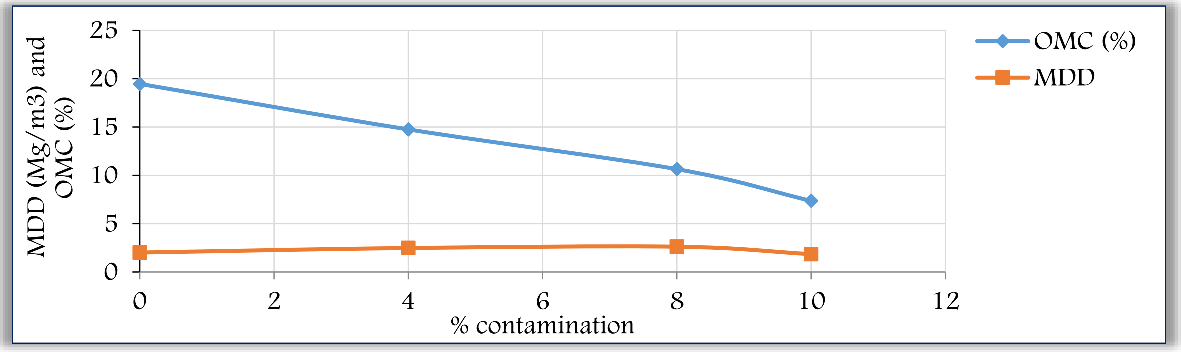

Figure 9: OMC and MDD against different % contamination for kerosene contamination

Table 1: Result on clay soil with 0% and 4% Petroleum contamination

Results	% contamination											
	0%						4%					
	LL (%)	PL (%)	PI	SG	OMC (%)	MDD (mg/m³)	LL (%)	PL (%)	PI	SG	OMC (%)	MDD (mg/m³)
Petrol	37.70	26.70	11.00	2.00	19.46	2.01	40.85	30.70	10.15	1.76	17.84	2.18
Kerosene	37.70	26.70	11.00	2.00	19.46	2.01	38.65	27.90	10.75	1.84	14.75	2.48
Spent Engine oil	37.70	26.70	11.00	2.00	19.46	2.01	39.52	29.20	10.32	1.64	17.01	1.98

Table 2: Result on clay soil with 8% and 12% Petroleum contamination

Results	% contamination											
	8%						12%					
	LL (%)	PL (%)	PI	SG	OMC (%)	MDD (mg/m³)	LL (%)	PL (%)	PI	SG	OMC (%)	MDD (mg/m³
Petrol	42.66	32.85	9.81	1.41	15.30	2.23	44.24	34.82	9.42	1.21	12.78	1.77
Kerosene	40.07	29.90	10.17	1.51	10.64	2.62	41.33	31.48	9.85	1.35	7.36	1.84
Spent Engine oil	43.72	30.15	13.57	1.49	14.24	2.37	47.47	30.92	16.55	1.05	11.52	1.79

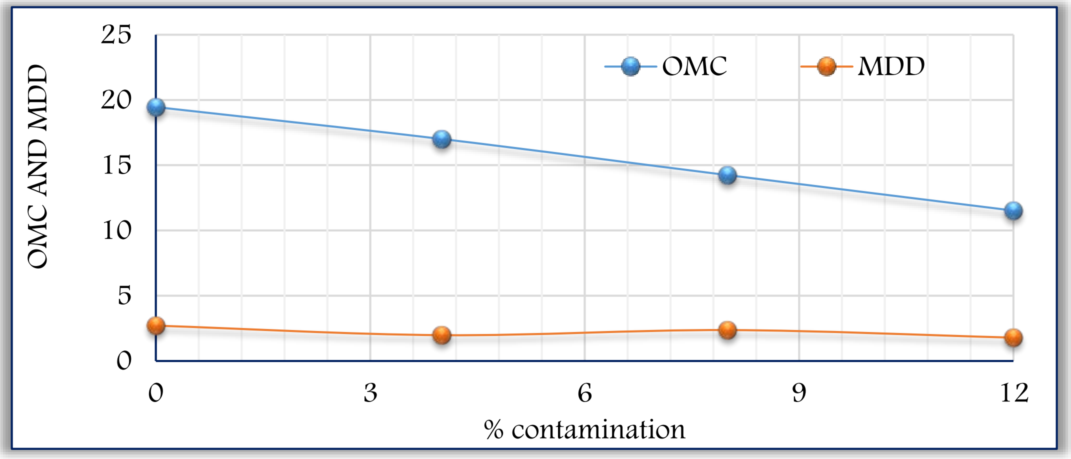

Figure 10: OMC and MDD against % contamination for spent engine oil contamination

4. CONCLUSION

The variables possessed by the clay soil are hydraulic gradient and infiltration capacity and the variables possessed by the petroleum are viscosity and density. These variables influenced the geotechnical properties of the petroleum contaminated soil. The viscosity of the petroleum enhanced the sliding of the clay soil particle due to lubrication. Also, the petroleum reduced the amount of water in the pore space, which caused a reduction in the compaction characteristics of the clay soil. Petroleum contamination makes the contaminated soil to appear aggregated but the contaminated soil at least to the level investigated in this research (i.e. up to 12% contamination) can be used as subgrade material in road construction.

It can be concluded that petroleum pollution on clay soil affects its geotechnical properties.

References

[1] Acar, Y. and Ghosh, A., 1986. Role of activity in hydraulic conductivity of compacted soils permeated with acetone. Proceedings of Environmental Geotechnology Conference 1: Pp 403-410.

[2] Adesunloye, M.O., 1987. Investigating the problem soils of Nigeria. 9th Regional Conference on Soil Mechanics and foundation Engineering for Africa 1: Pp 103-112.

[3] Ainley, D., Lazonby, J. N. and Masson, A. J., 1985. Chemistry in Today's World, London: Bell & Hyman Ltd,.

[4] Alainachi, I. H. and Alobaidy, G. A., 2010. The Effect of Basra Gulf Salt Water on the the proctor Compaction and CBR Test result of Soil Sample at Baniyas City, Abu Dhabi, UAE. Electronic Journal of Geotechnical Engineering 14: Pp 1-15.

[5] Barbour, S. and Yang, V., 1993. A review of the influence of clay-brine interactions on the geotechnical properties of Ca-montmorillonitic clayey soils from western Canada. Canadian Geotechnical Journal 30(6): Pp 920-934.

[6] Fang, H. and Kim, T., 2006. Leachate leakage from landfill: Causes and mechanisms. In Sarsby and Felton eds. Geotechnical and Environmental Aspects of Waste Disposal Site. London: Taylor & Francis Group.

[7] Fang, H. Y. and Daniels, J., 2006. Introductory geotechnical engineering: an environmental perspective. New York: Spon Press.

[8] Filauro, G., Andreotti, G., Arlotti, D. and Reisiger, H.J., 1998. Blow out of Trecate 24 crude oil well: How bioremediation techniques are solving a major environmental emergency in a valuable agricultural area. Contaminated Soil 98: Pp 403-412.

[9] Fine, P., Graber, E.R. and Yaron, B. 1997. Soil interactions with petroleum hydrocarbons: abiotic processes", Soil Technology, 10: Pp 133– 153.
[10] Fingas M.F., 2004. Modeling evaporation using models that are not boundary-layer regulated. Journal of Hazardous Materials, 107: Pp 27-36.
[11] Fojtova, L., Marschalko, M., Franekova, R. and Kovar, L., 2009. Study of Compatibility of Methods for Liquid Limit Measurement according to Czech State Standard and newly adopted European Standard. Geoscience Engineering 55 (1): Pp 55-68.

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