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# EFFECT OF USED MOTOR OIL CONTAMINATION ON GEOTECHNICAL PROPERTIES OF CLAY SOIL IN UYO-AKWA IBOM

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## *ABSTRACT*

This paper was carried to investigate the effect of used motor oil contamination on geotechnical properties of Clay soil in UYO-AKWA IBOM. In view of this, evaluating possible changes caused by waste motor oil spills in the environment and determining the suitability of some engineering construction materials in the area of study were made possible. The contaminated soil was prepared by adding different percentages of waste motor oil; 4%, 8%, 12% and 16%. The particle size distribution test (sieve analysis), compaction test, Atterberg limit test and California Bearing Ration (CBR) test were determined in both contaminated and uncontaminated sandy and clay soils. The result showed an increase in particle size distribution of soil after carrying out the analysis: reduction in optimum moisture content and maximum dry density for compaction test, reduction in liquid limit, and also a reduction in CBR value due to waste motor oil contamination. These show that the presence of waste motor oil has a remarkable effect on geotechnical properties of clay soils.

**Contribution/ Originality:** This study is one of the very few studies which have investigated the effect of oil spill on the geotechnical properties of clay soils. The increase in used motor oil content reduces the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of the soil. It affects the Atterberg limits of the soil. The California Bearing Ratio (CBR) of the soil also reduces with it. The work will assist Civil and Structural engineers in choosing materials for foundation structure and construction when working on such soils.

## 1. INTRODUCTION

For many years now, changes in soil properties resulting from contamination have been a subject of interest to many researchers. Oil spills in most cases are accidental especially during transportation on land and sea; as leakage from storage tanks or during oil servicing processes.

Hydrocarbon itself can separate into solid, liquid and gaseous states which remain closely to the leaking places or migrate within the ground water system or absorbed on grains as immobile residual liquids [1]. Clay soil being electrochemically active is mostly affected whenever the environment is contaminated by fluid substances. The properties of soil and migration substances control the rate of migration, changes in composition and properties of migrating substances. In addition, hydrocarbon contains undissolved components of Dense Non-Aqueous Phase Liquid (DNAPL) and Light Non-Aqueous Phase Liquid (LNAPL) which can travel vertically and horizontally in long distances under gravitational influence which require different treatment depending on the nature and extent of contamination [2].

When spilling occurs, the liquid hydrocarbon under gravity moves down to the groundwater, saturating the soil partially in its pathway. At the groundwater table, there might be an horizontal spread of the liquid by migration within the capillary zone, thereby further saturating the soil [3]. When an oil spill or leakage occurs, the accompanying contamination will alter both the quality of the sol and its physical properties. Saturation of soil with fluid characterized by physiochemical properties that differ from water has been found to have a deteriorating effect on its geomechanical and filtration parameters, plasticity, swelling and other properties. The effect is even worse in engineering practices. One of such effect is that of temperature as it impacts on the strength, permeability and compaction of the soil. It can also result in failure of existing structures especially when the contamination causes significant increase in soil plasticity, loss of its bearing capacity, increases its settlement and prevent drainage of water and other liquid [4].

### 1.1. Aim and Objectives of the Study

The aim of this work is to determine the effect of waste oil on clay soil by evaluating the geotechnical properties of the soil.

The objectives of the study include among others;

- To assess the variation of soil enfolded with waste motor oil and soil without same.
- To evaluate the risk of waste motor oil contamination of soil on foundation structures and constructions.

### 1.2. Definition of Terms

Motor oil is any of the various developed lubricants consisting of oil enhanced with additives that are used for lubrication of internal combustion engines. It is derived from petroleum-based and non-petroleum synthesized chemical compound and are mainly blended by using base oil composed of organic compounds consisting entirely of carbon and hydrogen.

Waste motor oil may be described as dirty oil that had been used in a vehicle which has been drained out so as to avoid clogging of engine parts.

Clay oil may be defined as a mixture of natural deposits of fine grained materials and is formed by the weathering of certain rocks. They are red in colour ranging from through bright to brown shades.

Geotechnical test is known as the different types of tests being carried out on soil samples in order to determine the soil bearing capacity, plasticity index of the soil, gradation of the soil and other properties.

For the purpose of this research, the following tests will be carried out: compaction test, Atterberg limit test, California bearing ratio (CBR) test and particle size distribution test.

## 2. DEFINITION OF WASTE MOTOR OIL

A lot of definitions have been put forward in the bid to simplifying and making waste motor oil clear to people. One of such definition is that put forward by the USEPA [5]. They defined waste motor oil as oil that has been refined from crude oil (or any synthetic oil) which has been used and as a result of such use, is contaminated by chemical impurities which contribute to chronic hazards as well as environmental hazards with global ramifications [6].

### 2.1. Constituent of Waste Motor Oil

According to Wang, et al. [7] waste motor oil is a mixture of several different chemicals including low and high molecular weight aliphatic hydrocarbons, aromatic hydrocarbons, lubricatives, additives, decomposition products, heavy metal contaminants such as aluminum, chromium, tin, lead, manganese, nickel and silicon that come from engine parts as they wear down.

### 2.2. Effect of Waste Motor Oil on Clay Soil

Construction Industry Research and Information Association CIRIA [8] defined lateritic soil as a soil with highly weathered material that is formed by the concentration of the hydrated oxides of iron and aluminum. This concentration may be by residual accumulation or by solution, movement and chemical precipitation.

According to Oyegbile and Ayininuola [9] the Maximum Dry Density (MDD) of motor oil contaminated soil decreases as the period of contamination increases. A test carried out by Wang, et al. [7]. Khamehchiyan, et al. [10] also showed that the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) of soil contaminated with waste motor oil decrease. Singh [11] reported that the load carrying capacity of oil saturated sand decreases with oil content. It has also been shown that the bearing capacity of waste motor oil contaminated soil is drastically reduced and made unsustainable for supporting engineering structures or plant growth by increasing toxic content of the soil Mashalah [12]. Murat and Mustafa [13] reported that there is a variation in the hydrocarbon content of waste motor oil and the concentration of this hydrocarbon affect the extent to which waste motor oil influence the geotechnical properties of clay soil. According to a study carried out by Youdeowei [14] to investigate the effect of hydrocarbon on engineering characteristics of oil contaminated soils, it was observed that the change hydraulic conductivity of a particular soil can be associated with the changes in the soil and the soil fabrics when moulding pore fluid. He added that as a result of oil contamination, various liquid interact with chemically active soil of clay and sand particles, altering their behaviors.

### 2.3. Compaction Test

In geotechnical engineering, soil compaction is the process in which a stress applied to a soil causes densification as air is displaced from the pores between the soil grains.

Compaction of a material is achieved at Optimum Moisture Content (OMC). This means, a soil in a dry state will not be compacted unless water is added. For the purpose of this research, the proctor compaction test will be used and it is defined according to Das [15] as the laboratory method used to determine the optimum moisture content at which a given soil type will become most dense and achieve its maximum dry density. The term 'proctor' is in honour of R. R. Proctor who in 1933 showed that the dry density of a soil for a given compactive effort depends on the amount of water the soil contains during soil compaction.

The testing described is generally consistent with the American Society for Testing and Materials (ASTM) standards and is similar to the American Association of State Highway and Transportation Officials (AASTHO) standards.

### 2.4. Atterberg Limit

Albert Atterberg, a Swedish agricultural scientist in 1911, considered the consistency of soil and proposed a series of tests for defining the properties of the cohesive soils. These tests indicate the range of plastic states (that is, the property of cohesive soils which posses the ability to undergo changes of shape without rupture) and other state [1].

According to Alban [16] Atterberg limits are a basic measure of the critical water contents of a fine grained soil: its shrinkage limit, plastic limit and liquid limit. As a dry, clayey soil takes on increasing amount of water, it undergoes distinct changes in behavior and consistency.

### 2.5. California Bearing Ratio (CBR)

Material including recycled material for use in road and airfield pavements. It may be thought, therefore as an indication of the strength of the soil relative to that of crushed rocks [17]. It is primarily intended for, but not limited to evaluating the strength of cohesive materials having maximum particle sizes less than 199mm. This is a relatively simple test that is commonly used to obtain an indication of the strength of a subgrade soil, sub base and base course.

### 2.6. Particle Size Distribution

The particle-size distribution (PSD) of a powder, or granular material, or particles dispersed in fluid, is a list of values or a mathematical function that defines the relative amount, typically by mass, of particles present in the soil according to size. It is also a practice or procedure which is used to assess the particle size distribution of granular materials. It can be performed on any type of non-organic and organic granular materials which are sands, crushed rocks, clays, granites and a wide range of manufactured grains. It is also known as GRADATION TEST. The standard specification for sieve analysis test is a graph that has a curve as that of an OGIVE which represents a well graded soil. Gupta and Srivastava [17] said that the particles distribution is critical to the behavior of the soil under loads and in contact with water that if the particle size distribution of a particular soil is known, it is possible to make good prediction of how it would behave as a foundation for buildings, dams, roads, e.t.c.

## 3. SAMPLE COLLECTION

The soil samples used in this work were collected from University of Uyo main campus and the waste motor oil was gotten from Abak road mechanic workshop, Uyo. The soil samples were divided into five portions, each weighing 5kg. Each portion of soil sample was mixed thoroughly with waste motor oil at different percentages of 0, 4, 8, 12 and 16. The samples were kept for two weeks to attain a homogenous mixture. The tests were generally carried out in accordance with the procedure outlined by British Standard Institution (BSI), 1990 in Ukpong and Umoh [4]

### 3.1 Determination of Compaction, Atterberg Limit, Particle Size Distribution and California Bearing Ratio

The soil sample was divided into five parts and each part was mixed with 0%, 4%, 8%, 12% and 16% of waste motor oil. The mixed samples were then stored in a bag for three days for proper mixing and also to attain a homogenous mixture.

For compaction test, the West African Standard method was used. The compaction equipment is as follows: compaction tray, proctor mould with collar of diameter 152.4mm, mould height was 127mm, Rammer weight of 4.5kg, straight edge, weighing balance, moisture content tins. Compaction was carried out on the samples. For Atterberg Limit, this method involves conducting test in order to determine the minimum water content at which the soil begins to deform as plastic or liquid respectively. The apparatus used include: liquid limit device (casagrande machine), ground glass plate, gage, flat grooving tool. Water content for plastic limit was determined by rolling 20grams of soil passed through sieve number 40 (ASTM) and thoroughly mixed until the soil showed some sign of crumbling. The casagrande machine was used to determine the liquid limit of the soil sample. The particle size distribution test was carried out using a set of sieves duly arranged. The sieve mesh sizes were expressed in millimeters according to BS (1377) [18]. Also, the CBR test was carried out with the aid of a CBR machine. The machine runs a test for both top and bottom penetration of the soil in mould.

### 3.2. Sieve Arrangement

**Table-3.1.** A Typical Way of Arranging Sieves

| Sieve Number | Opening Size |
|---|---|
| 7 | 2.36 |
| 14 | 1.18 |
| 25 | 850 |
| 36 | 425 |
| 52 | 300 |
| 72 | 212 |
| 100 | 150 |
| 200 | 75 |

**Source:** The data was obtained when carrying out the work .Read the work closely

**Figure-3.1.** A Typical Diagram of Set of Sieves Duly Arranged
**Source:** Wikipedia

## 4. RESULT AND DISCUSSION

After carrying out series of tests on the contaminated and uncontaminated soil samples, the result showed some alteration on the geotechnical properties. For example, the result of the compaction test performed on the uncontaminated and variably contaminated soil using the standard proctor method is presented in Table 4.5. The Maximum Dry Density (MDD) and the Optimum Moisture Content (OMC) decrease as the waste motor oil is increased by percentage content. The behavior of the clay particles greatly influences the geotechnical properties of the soil. The waste motor oil coats itself around the individual clay particles preventing free interaction with clay particles. This is thought to be responsible for the reduction in the amount of water needed to reach its maximum unit weight as the waste motor oil is increased. It was observed that the Atterberg limit values for liquid limit, plastic limit and corresponding plastic index of the oil contaminated soil were drastically increased as the oil content in the clay so soil increases. Table 4.3. Again, the value of California Bearing Ratio (CBR) of the uncontaminated soil was higher than that of the contaminated soil. For the soaked and unsoaked samples, the CBR values decreased down to 8% content of waste motor oil and later increased as shown in Table 4.4. The details of these results are presented in the tables and graphs below.

**Table-4.2.** Physical Properties of Natural Clay Soil

| Characteristics | Quantity |
|---|---|
| % passing sieve number 0.075mm | 2.30 |
| Liquid Limit (LL) % | 31.60 |
| Plastic Limit (PL) % | 20.55 |
| Plasticity Index (PI) % | 11.05 |
| AASHTO Classification | A-2-4 (0) |
| Natural Moisture Content % | 15.75 |

**Source:** Wikipedia

**Table-4.3.** Atterberg Limit for Clay Soil

| WMO content (%) | Liquid Limit (%) | Plastic Limit (%) | Plasticity Index (%) |
|---|---|---|---|
| 0.00 | 40.20 | 18.50 | 21.70 |
| 4.00 | 42.50 | 20.95 | 21.55 |
| 8.00 | 48.00 | 21.20 | 26.80 |
| 12.00 | 51.70 | 22.67 | 29.03 |
| 16.00 | 55.95 | 25.95 | 30.00 |

**Source:** Wikipedia.org/wiki/Atterberg_limit

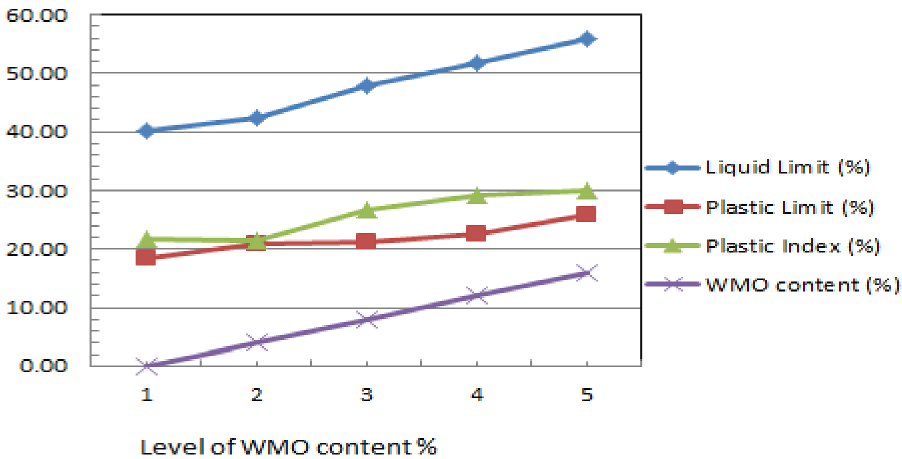


**Figure-4. 1.** Atterberg Limit for Clay Soil

**Source:** Plotted from the data in the work.Pls read the work well

**Table-4.4.** CBR Value for Clay Soil

| WMO Content % | Unsoaked CBR Value (kg) | Soaked CBR Value (kg) |
|---|---|---|
| 0.00 | 7 | 8.9 |
| 4.00 | 4.5 | 2.55 |
| 8.00 | 1.55 | 1.7 |
| 12.00 | 2.2 | 1.5 |
| 16.00 | 2.39 | 1.55 |

**Source:** Ffom exp. Data in the work

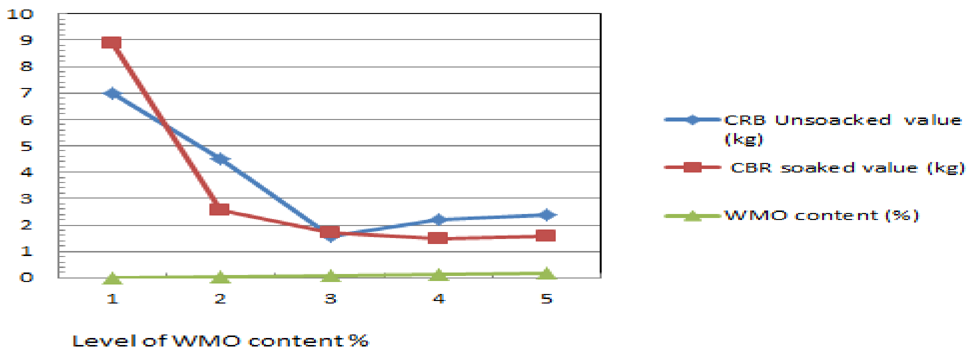


**Figure-4. 2.** CBR Values for Clay Soil

**Source:** Plotted from the data in the work. Pls read the work well

**Table-4.5.** Variations of MDD and OMC Values from Compaction Test on Different Oil Content of Clay Soil

| WMO Content % | MDD (%) | OMC (%) |
|---|---|---|
| 0.00 | 1.97 | 17 |
| 4.00 | 1.9 | 14 |
| 8.00 | 1.8 | 13.5 |
| 12.00 | 1.79 | 13 |
| 16.00 | 1.7 | 11.5 |

**Source:** The data was obtained when carrying out the work  Pls read the work closely

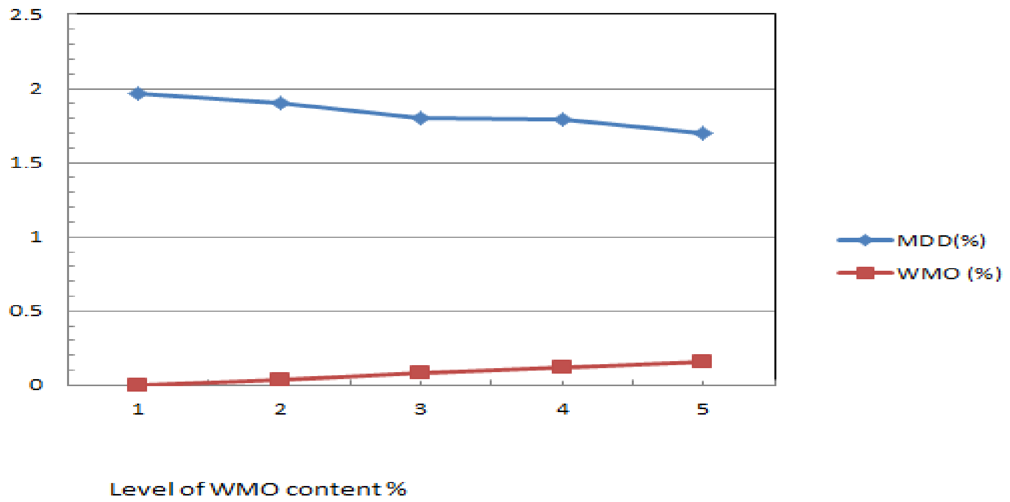


**Figure-4. 3.** Maximum Dry Density (MDD) for Clay Soil

**Source:** Plotted from the data in the work. Pls read the work well

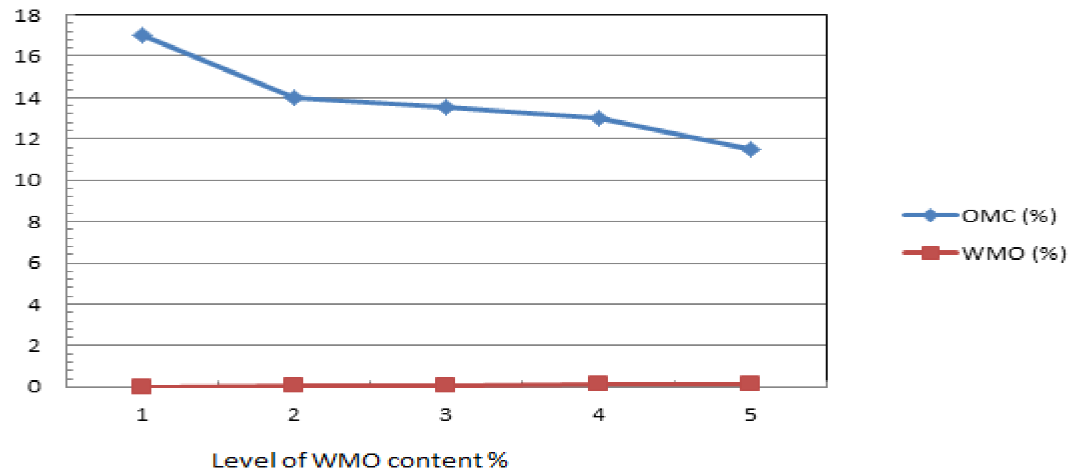


**Figure-4.4.** Optimum Moisture Content (OMC) for Clay Soil

**Source:** Plotted from the data in the work. Pls read the work well

## 5. CONCLUSION AND RECOMMENDATION

### 5.1. Conclusion

The presence of waste motor oil in soils has an effect on its geotechnical properties. The Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) reduce with increase in waste motor oil content. Waste motor oil also affects the Atterberg limit of the soil. The California Bearing Ratio (CBR) of the soil also reduces as the percentage of used motor oil increases. The particle size distribution of the contaminated soil is altered due to oil clotting on the soil. Due to changes resulting from the presence of waste motor oil on clay soil, proper analysis of soils in area prone to waste motor oil spills would help in choosing certain materials for foundation structures and construction.

### 5.2. Recommendation

From the result above, it is seen clearly that presence of used motor oil in clay soil alters its geotechnical properties; therefore, public enlightenment on the dangers of used motor oil spills should be conducted especially for residents of areas prone to the spills like mechanic workshops and dumpsites. There should also be improvement on drainage process in companies and mechanic workshops so as to minimize spillage. Also, Government should enact laws to force mechanic workshops and companies to thoroughly clean up the waste oil after spills. This would help reduce its frequency of occurrence and minimize its effect on soil.

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## REFERENCES

[1] Z. A. Rahman, U. Hamzah, and M. R. Taha, "Influence of oil contamination on geotechnical properties of residual soil," *American Journal of Applied Sciences*, vol. 7, pp. 954-961, 2010. View at Google Scholar

[2] B. R. Zogala, W. M. Dubiel, M. Zuberek, Rusin-Zogala, and M. Steininger, "Geoelectrical investigation of oil contaminated soils in former underground fuel base: Borne Sulinowo, NW Poland," *Environmental Geology*, vol. 58, pp. 1-9, 2009. View at Google Scholar | View at Publisher

[3] A. Tuncan and S. Pamukcu, *Predicted mechanism of crude oil and marine clay interactions. Environmental geotechnology, Usman and Acar (Eds.)*. Rotterdam: Balkema, 1992.

[4] E. C. Ukpong and I. Umoh, *Methods of testing soils for civil engineering purposes*. London: British Standard Institute, 1990, 2012.

[5] USEPA, "Managing used oil: Advice for small businesses EPA530–F–96–004," 1996.

[6] T. K. C. Udeani, A. A. Obroh, C. N. Okwuosa, P. U. Achukwu, and N. Azubike, "Isolation of bacteria from mechanic workshops soil environment contaminated with used engine oil," *African Journal of Biotechnology*, vol. 8, pp. 6301-6303, 2009. View at Google Scholar | View at Publisher

[7] J. Wang, C. R. Jia, C. K. Wong, and P. K. Wong, "Characterization of polycyclic aromatic hydrocarbon created in lubricating oils," *Water, Air and Soil Pollution*, vol. 120, pp. 381-396, 2000. View at Google Scholar

[8] Construction Industry Research and Information Association CIRIA, *Laterite in road pavements*. London: Special Publication 47, Transportation Road Research Laboratory, 1998.

[9] O. B. Oyegbile and G. M. Ayininuola, "Laboratory studies on the influence of oil spillage on lateritic soil shear strength: A case study of Niger Delta area of Nigeria," *Journal of Earth Science and Geotechnical Engineering*, vol. 3, pp. 73-83, 2013. View at Google Scholar

[10] M. Khamehchiyan, A. H. Charkhabi, and M. Tajik, "Effects of oil contamination on geotechnical properties of clayey and sandy soils," *Engineering Geology*, vol. 89, pp. 220-229, 2007. View at Google Scholar | View at Publisher

[11] S. K. Singh, "Studies on soil contamination due to used motor oil and its remediation," *Canadian Geotechnical Journal*, vol. 46, pp. 1071-1083, 2009. View at Google Scholar | View at Publisher

[12] K. Mashalah, "Effects of crude oil contamination on geotechnical properties of clayey and sandy soils," *Engineering Geology*, vol. 89, pp. 220-229, 2007. View at Google Scholar | View at Publisher

[13] O. Murat and Y. Mustafa, "Effect of organic fluids on the geotechnical behavior of a highly plastic clayey soil," *Applied Clay Sciences*, vol. 48, pp. 615-621, 2010. View at Google Scholar | View at Publisher

[14] P. O. Youdeowei, "The effects of oil pollution and subsequent fire on the engineering properties of soils in the Niger Delta" *Engineering Geology and Environment*, vol. 67, pp. 119-121, 2008. View at Google Scholar | View at Publisher

[15] B. M. Das, *Mechanical behavior of an oil contaminated sand. Envir Geotech, Usmen and Acar, Eds.* Rotterdam, The Netherlands: Balkema Publishers, 1992.

[16] S. A. Alban, "The effect of temperature on the engineering properties of oil contaminated sand," *Environmental International*, vol. 24, pp. 153-161, 1997. View at Google Scholar | View at Publisher

[17] M. K. Gupta and R. K. Srivastava, "Evaluation of engineering properties of oil contaminated soils," *Journal of the Institute of Engineering, India. Civil Engineering*, vol. 90, pp. 37-42, 2010. View at Google Scholar

[18] BS (1377), *Methods of testing soils for civil engineering purposes*. London: British Standard Institute, 1990.

## BIBLIOGRAPHY

[1] Colorado Department of Public Health and Environment, *Monitoring and removal or treatment of contaminated soil*. USA: Colorado State, 2003.

[2] Habib-Ur-Rehman, S. N. Abdul Jauwad, and T. Akram, "Geotechnical behavior of oil contaminated fine-grained soils," *Electronic Journal of Geotechnical Engineering*, vol. 12, 2007.

[3] E. C. Ukpong and I. Umoh, "Effects of crude oil spillage on geotechnical properties of laterite soil in Okorote, Eastern Obolo,"*International Journal of Engineering and Applied Sciences*, vol. 7, pp. 12-24, 2010.

[4] A. R. Zulfahmi, "Influence of oil contamination on geotechnical properties of basalt residual soil," *American Journal of Applied Sciences*, Vol. 7, pp. 954-961, 2010. *View at Google Scholar*