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Effects of Leachate Contamination on Some Geotechnical Properties of Lateritic Soil

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Abstract

This paper presents the geotechnical properties of artificially leachate-contaminated and uncontaminated soils in order to study the effects of the contaminant on the soils' behavior when used for engineering purposes. 4 portions of lateritic soil samples were artificially contaminated with 5, 10 and 20% leachate and respective geotechnical properties were determined. Results showed that leachate contamination proportionally increased the Atterberg limits and permeability values for all contaminated soils, but decreases in compaction parameters. For compaction tests, maximum dry density decreased from 15.9kN/m^3 in the control sample to 14.4kN/m^3 in contaminated soil at 20% leachate concentration. The coefficient of permeability values increased with increase in leachate content. It was observed that addition of leachate has adverse reducing effects on the strength and hydraulic properties of the contaminated residual soil. Thus, use of leachate-contaminated soils in geotechnical engineering works should be avoided since it is inimical to life, money and properties.

Keywords: Leachate, contaminated soil, residual soil, compaction, Atterberg limits.

1. Introduction

Lateritic soils constitute an important unit of soil in parts of Nigeria. It is common and abundantly found as near surface material (below humus layer) within soil profile, especially in the southwestern Nigeria. Lateritic soil, in its natural existence sometimes possess good engineering properties that have made it useful as fill, road, dam, building bricks and barriers in sanitary landfill (Mesida, 1978; Ola, 1980; Alao, 1987, Ogunsanwo, 1988; Ige, 2007, 2010;

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and Ige *et al.*, 2011). Lately, due to increased urbanization and waste generation in Nigerian cities, this unit of soil layer has been turned to repository of solid and liquid waste by government agencies and individual. Leachate generation within the waste is encouraged by the process of the decay of organic component of the waste in the presence of chemically active water. According to Stevenson and Buttler (1969), humic substances with functional group such as carboxyl, carbonyl and phenolic hydroxyl are produced from the decay of organic component.

Effects of different impurities on natural properties of lateritic soils have been studied by several researchers with various deductions (Aiban, 1998; Shin *et al*., 1999; Hong *et al.*, 2005). Sunil *et al.* (2006**)** reported that the chemical and geotechnical properties of lateritic soils are altered by increasing content of pH while Indrawan *et al.* (2006) concluded that increasing amount of coarse-grained materials increased the saturated permeability and reduced the shrinkage potential of residual soil. A number of other related studies were carried out in order to investigate the geotechnical behavior of oil contaminated soil (e.g. Rahman *et al.*, 2007; Khamehchiyan *et al.*, 2010 and Rahman *et al.*, 2011). They concluded that oil contamination significantly reduced Atterberg limits, maximum dry density, permeability and strength properties of soils. George and Beena (2011) artificially contaminated soil with proportion of municipally generated leachate and discovered that permeability and shear strength increased while consistency limits values reduced with increasing percentage of leachate.

In cities of Nigeria, sources of wastes generation are on the increase and irrational disposal of these wastes on open or excavated lands/dumpsite creates source of soil pollution due to generation of leachate. These dumpsites, when closed or abandoned, are commonly acquired by government agencies or individual for development of civil engineering works such as shopping complex, bank, residential etc. The effects of leachate-soil interaction on the underlying soil at such sites in Nigeria have not been well documented. However, such interaction may weaken the strength of soil (Orlov and Yeroshicheva, 1967), thus limiting their application in civil engineering works or making the superstructure a potential death trap. Thus, this paper presents an assessment on effects of leachate contamination on some geotechnical properties of lateritic soil.

2. Materials and Methods

Soil

About 5kg of weathered lateritic sample, derived from a granite-gneiss along Asa dam road, 500meters to Dangote Flour Mill (Fig. 1) was collected for the purpose of preparing the leachate-contaminated samples. The disturbed sample was collected from a road-cut between 14th and 17th July, 2011, and stored in an air-tight plastic container before being air dried at room temperature for 72hours. The sample was pulverized into powdery state and air-dried for two weeks while analyses of parameters were performed between 25th July and 28th August, 2011.

Dry sieving and hydrometer techniques were used for particle size distribution analyses. Particle size distribution, specific gravity, consistency limits, compaction, and coefficient of permeability tests for soil were carried out using the British Standard Institute procedure, BS 1377: 1990. Further tests of the effects of leachate on geotechnical properties were carried out on contaminated soils. Contaminated soil was divided into three, each containing different proportions of leachate in order of 5, 10 and 20% of dried weight. The contaminant was thoroughly mixed with soil and the mixture was permitted to cure in closed container at ambient temperature for 7 days.

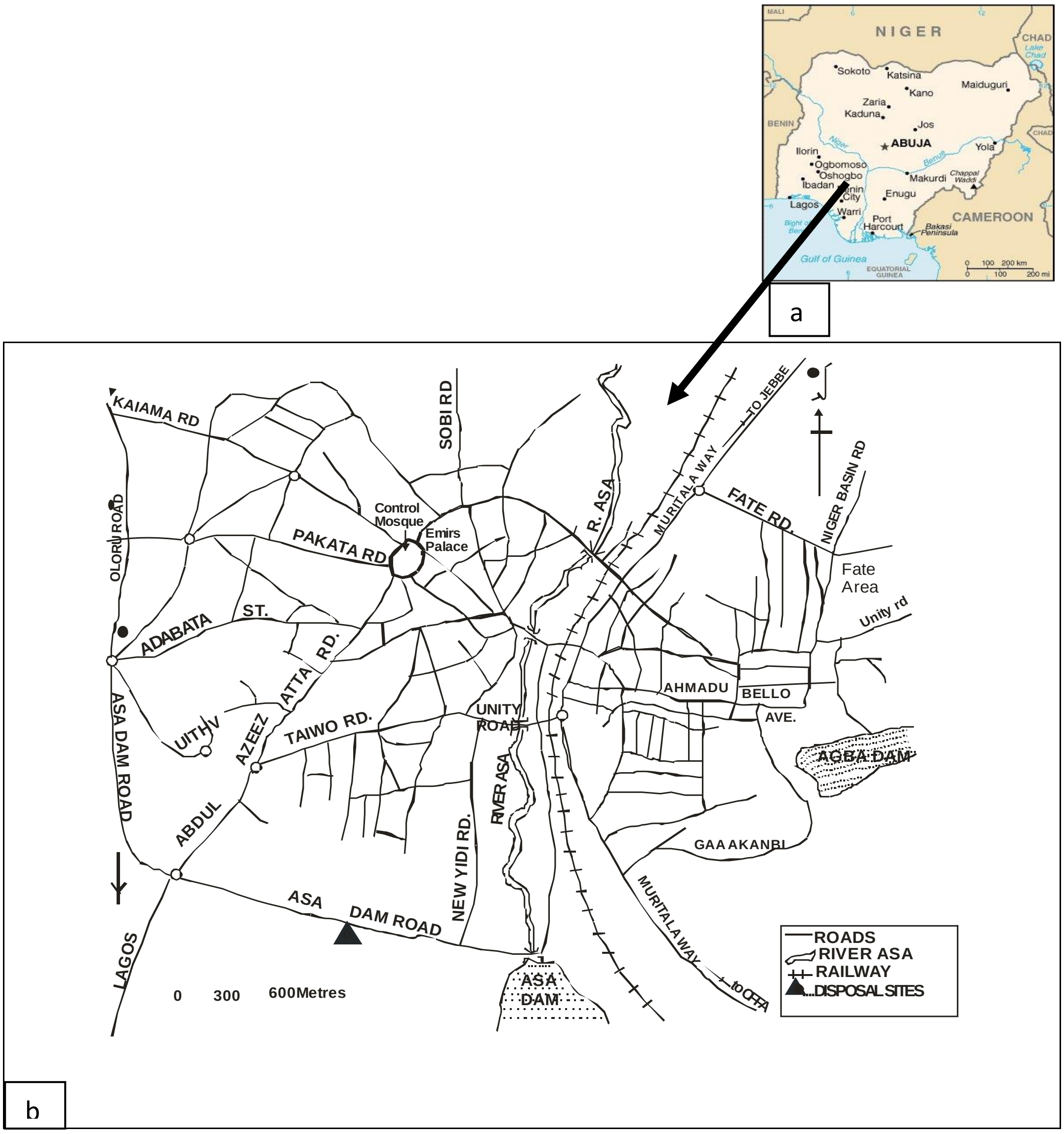

Fig. 1: (a) Major cities in Nigeria, (b) Ilorin road network showing Sample Location map along Asa Dam road (after Ige, 2011).

Leachate

Ten (10) litres of raw sample of leachate was collected from the base of over 20 years old waste dumpsite (at Amilegbe bridge) in Ilorin, Nigeria. The dumpsite receives both hazardous and non-hazardous waste (domestic, industrial, hospital, etc), which are the common waste generated in this part of the country (Ige, 2010). The leachate has the following characteristics: temperature = 21^0C, density = 0.786kg/l, colour = darkish brown. A filter paper was placed on each face of the soil specimen so as to prevent the clogging of the perforated disks by the soil fines. After placing the bottom and top plate of the falling head permeameter, the nuts were fastened and assembled properly. The permeameter was then connected to a stand pipe (when testing uncontaminated, soil the stand pipe was filled with distilled water and during testing of contaminated soil, the stand pipe was filled with leachate). The soil was saturated by allowing permeant (leachate) to flow continuously through the sample from the stand pipe. Saturation of the soil sample was ensured under steady state flow conditions. The coefficient of permeability was calculated with the relevant equation:

$$\frac{k=2.303\ aL\ Log_{10}\left(h_1/h_2\right)}{At}, \tag{1}$$

k = coefficient of permeability, a = cross sectional area of stand pipe (cm^2), L = height of soil sample (cm), A = cross sectional area of sample (cm^2), $h_1$and h_2 = initial and final height of permeant in stand pipe (cm), t = time taken for drop from $h_1$to h_2 (sec).

3. Results and Discussion

Grain size analysis

The basic geotechnical properties of the control sample are presented in Table 1. Grain size distribution analysis revealed 6% gravel, 47% sand and 47% fine. The results of the liquid limit (w_L), plastic limit (wp) and plasticity index (Ip) on the contaminated soils at 0, 5%, 10%, 20% proportion by weight are summarized in Table 1. It is clear from that liquid limit, plastic limit and plasticity index increase with increase in leachate content. This trend may be due to polarized nature of the moisture content. The polarized water is attracted by negatively charged clay surface, thus influences the orientation of water around clay particles. Gillot (1987) reported that clay soils with non-polarized fluid do not have plasticity properties. Crude oil-waste is a non-polarized fluid, as the oil is evenly mixed with the samples; it covers the grains and reduces water-soil interaction. This brings about increase in the consistency limits as the leachate content increases.

Compaction Tests

Compaction is carried out to improve qualities of soils for suitability in engineering construction works. Light energy (standard proctor) of compaction was used to compact both control and artificially contaminated samples. Figures 2 and 3 showed the relationship between leachate content, optimum moisture content (OMC) and the maximum dry density (MDD) as the leachate content increases. This is consistent with other related studies by Shah *et al.* (2003) on oil contaminated soils. The MDD values for contaminated soils showed a sharp and

Table 1: Geotechnical characteristics of control and oil-contaminated soil samples.

Parameters	Control Sample	Percentage of dry weight of base oil		
	0 %	5.0%	10.0%	20.0%
Liquid Limit	48.5	51.4	56.3	61.7
Plastic Limit	23.3	25.2	28.4	33.4
Plasticity Index	25.2	26.2	27.9	28.3
Specific Gravity	2.67	2.67	2.66	2.63
Density Tests(g/cm^3)				
Bulk Density	1.27	1.72	1.79	1.83
Dry Density	1.25	1.18	1.18	1.20
Compaction Tests				
Optimum Moisture Content (%)	20.3	20.8	22.0	24.5
Maximum Dry Density(KN/m^2)	15.9	15.6	15.5	14.4
Grain Size Distribution of control sample	Gravel=6%	Sand=47%,		Fine =47%

Atterberg Consistency Limits

consistent departure from 15.9kN/m^2 obtained for control samples to 15.6-14.4kN/m^2 in contaminated soil as the proportion of leachate increases. These results are consistent with Shah *et al.* (2003) study on oil-contaminated material. For the energy of compaction, the MDD consistently decrease with increase in leachate content while the OMC increases (Fig. 3). These could be due to the lubricating effect of the presence of leachate which prevents effective compaction. Also, the presence of leachate reduces the amount of water content needed to reach

MDD. The results are similar to findings of Al-Sanad *et al.* (1995) who reported that at excess oil-waste content, the shape of the curve will be odd.

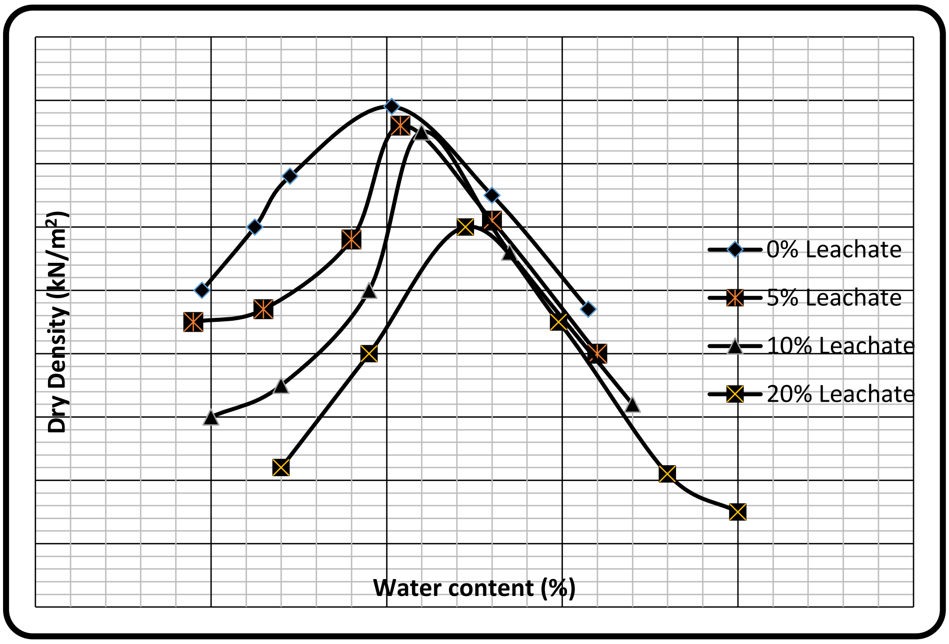

Fig. 2: Compaction curves for lateritic soils with different Leachate content.

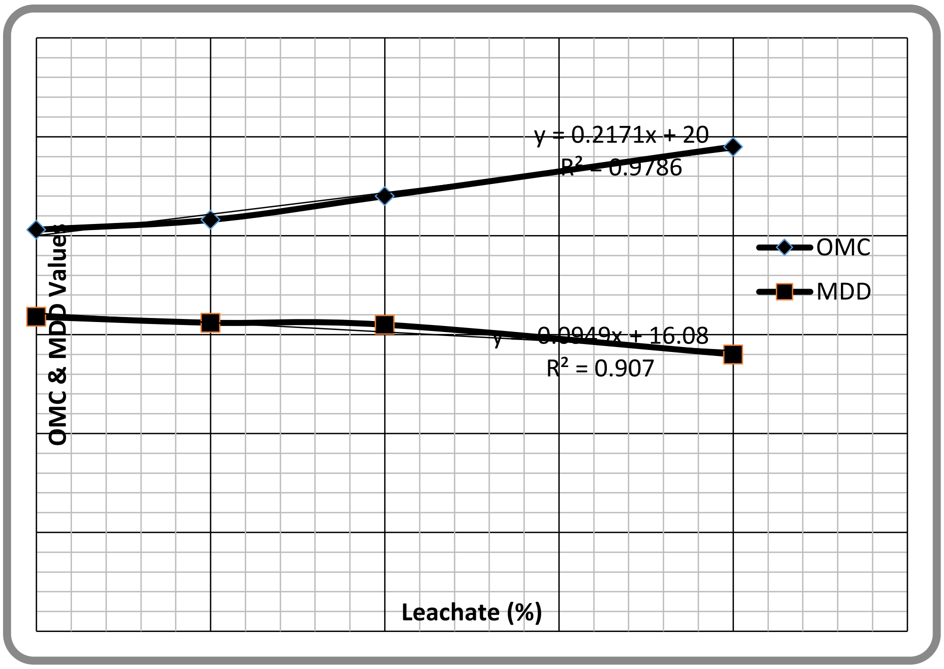

Fig. 3: Relationship between compaction parameters and Leachate content.

Co-efficient of Permeability (k)

The coefficient of permeability of any soil is dependent on several factors such as fluid velocity, pore-size distribution, grain size distribution, void ratio, roughness of mineral particles, and degree of saturation (Das, 2007). With the falling head permeability tests carried out on both contaminated and uncontaminated samples to compare the coefficient of permeability, there was increase in leachate concentration as the coefficient of permeability of the contaminated soil increases (Fig. 4). This increase in coefficient of permeability is attributed to chemical reaction between the leachate and the clay minerals. It is reported that strongly acidic and strongly basic liquids can dissolve clay minerals (Uppot and Stephenson, 1989). The dissolution of clay mineral particles by leachate increases the effective pore space and hence, the hydraulic conductivity increases. Sunil *et al.* (2006) reported that the cementing agents in soils help to bind the finer particles together to form aggregates. However, strongly acidic conditions lead to the destruction of soil structure. Hence as the particles are percolated by permeant, they clog pore spaces. But, as dissolution progresses in the zones of clogging, particles will be removed and the hydraulic conductivity increases.

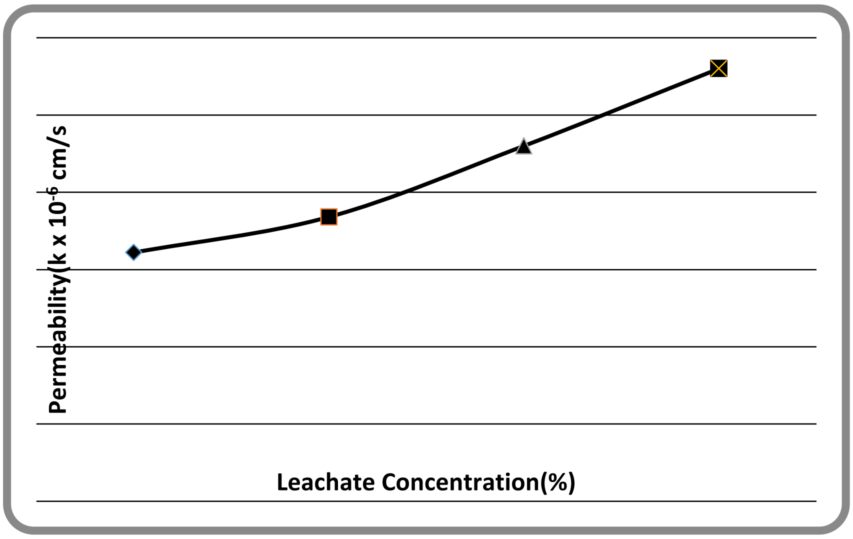

Fig. 4: Variation in coefficient of permeability at different leachate content.

4. Conclusion

In this paper, effects of leachate contamination on some geotechnical properties were carefully investigated on lateritic soils with the index, compaction and permeability test performed in accordance with the BS standard. The Atterberg limits values of contaminated soils were higher than those of uncontaminated soils while the maximum dry densities also dropped as leachate content increases above 5% in contaminated soils. Similar behaviour was observed on compaction and coefficient of permeability properties of the investigated soils. There was a noticeable departure in the values of OMC and MDD of control and contaminated soils as the leachate content increases. OMC increases with increasing content of leachate while MDD decreases. The coefficient of permeability values also increase in values with increasing percentage of leachate content in contaminated soils.

The results showed that leachate contamination on soil has adverse influence on geotechnical properties of lateritic soil. Thus, use of old or abandoned open dumpsites civil engineering construction of superstructures should be discontinued because of potential defects on soil strength, toxic consequences on lives, properties and eventual wastage of money.

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