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# EFFECT OF ABATTOIR WASTEWATER ON GEOTECHNICAL PROPERTIES OF LATERITIC SOIL

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**Abstract**

This study focuses on influence of abattoir wastewater on some geotechnical properties of lateritic soil. Abattoir wastewater (AWW) and lateritic soil were obtained from Ilokun abattoir and Ilokun borrow pit, respectively. AWW was subjected to physico-chemical analysis at fresh state and after 14days. Chemical analysis was carried on the uncontaminated/natural soil sample in order to determine its degree of laterization. The soil samples were contaminated with AWW at varied rate of 5, 10 and 20 % of dry weight of lateritic soil. The geotechnical properties of the soil sample at the varying percentages of contamination were determined and compared with natural soil properties. Results of tests showed a corresponding increase in the liquid limit from 43 to 70% and consequently increase plasticity index from 18.27 to 37%. The addition of AWW lowered the Maximum Dry Density (MDD) from 1905 - 1420kg/m$^3$ while California Bearing Ratio (CBR) values reduced from 23.42% to 6.14%. However, cohesion and rate of permeability(k) improves with increased dosage of contaminant. Chemical reactions between the soil grains and abattoir wastewater were responsible for the degradation of the soil grains. Hence, it can be concluded that Abattoir wastewater adversely affect the geotechnical properties of the soil.

Keywords: Abattoir, Contamination, Geotechnical properties, Lateritic soil, Wastewater.

## 1. Introduction

Geo-environmental engineering is a discipline studying effect of varying environmental activities, be it natural and man-made on earth and its component. The interaction of soil with various materials brings about soil contamination. The contamination is mainly due to formation of toxic compounds which follows the chemical reaction between inherent elements present in the materials and soil. These materials emanate from mining, quarrying, commercial, agricultural and industrial activities. These materials (pollutants) can cause microstructure changes of soil which will in turn affect engineering properties and therefore threaten the engineering quality of such soil [1]. Unfortunately, in developing countries there are still impediments to efficient waste management and these are due to lack of adequate technology, poor policy formulation and implementation, political meddling, lack of human and financial resources [2, 3].

Therefore, the indiscriminate and pitiable emissions and (or) discharges of pollutant resulting from agricultural and commercial activities, industries, automobiles, disposal of solid/hazardous waste substances negatively impacts the environment. Key among the sources of this contamination and sometimes environmental pollution is abattoir wastewater. Abattoir is a dedicated facility where conversion of animals to meat takes place through slaughtering [4]. In Nigeria, the situating of these slaughterhouses is usually haphazardly fixed without proper monitoring and regulation thereby causing poor handling of abattoir solid waste and wastewater [5]. Williams and Dimbu [6] reported that abattoir wastewater contains some chemicals and hence be treated before its release to the environment. Elemile et al. [7] however reported that abattoir activities adversely impact soil properties.

In Nigeria, apart from the fact that abattoir is known to have the capacity to contaminate both surface and groundwater; it also affects soil negatively [8, 9]. This is because abattoir wastewater is usually not treated prior to disposal. Abattoir waste (solid and liquid) contributes to heavy metals level and cause a rise of organic matter present in soils [10]. The impact of these liquid wastes on the soil properties have been assessed by studying thoughtful synthesis and (or) on-field assessment of contaminated soil by various researchers. Although, research is limited on influence of abattoir activities on geotechnical properties of lateritic soil in developing country which incidentally is notoriously known to be behind in the area of efficient waste management. Several authors including Akinwumi et al. [11], Ojuri and Ogundipe [12], Oluwatuyi et al. [13], Otunyo and Anele [14], and Raveendran and Poulose [15] have studied the effect of spent engine oil, motor oil, diesel on geotechnical properties of soil and their findings showed that their inclusion/addition have undesirable effects on soil properties.

However, Oluremi et al. [16] also investigated the effect of cassava wastewater from agricultural activities on soil properties. Their findings showed that contamination affects the plasticity of soil and consequently renders soil unsuitable for road applications. Soil-waste interaction influences almost all soil properties and therefore there is a need for a vivid knowledge of the basic properties of the wastes and their likely effects on geo-chemical properties of soil so that a reasonable recommendation can be made for engineers. Hence, the study is inclined to assess the chemical properties of Ilokun abattoir wastewater, and some geotechnical properties of lateritic soil contaminated with the abattoir wastewater.

## 2. Material and Methods

### 2.1. Study area (Ilokun abattoir and borrow pit)

The study area as presented in Fig. 1 is the Abattoir and Borrow Pit located at Ilokun along Ekiti State University Road, Ado - Ekiti, Ekiti State, Nigeria. The abattoir was built and managed by Ekiti State Government, Nigeria. Lateritic sample was obtained at Latitude 7°41' 25" N and Longitude 5°15' 11" while the abattoir wastewater was taken at 7°41' 34" N and Longitude 5°15' 22" E. Ado-Ekiti (an evolving city) is the state capital of Ekiti State with mean annual temperatures range between 24°C and 27°C and annual rainfall varying between 1500mm and 3500mm. The main rock type is characteristically charnockitic rock weathered into reddish to dark brown medium grained lateritic layer of considerable thickness [17].

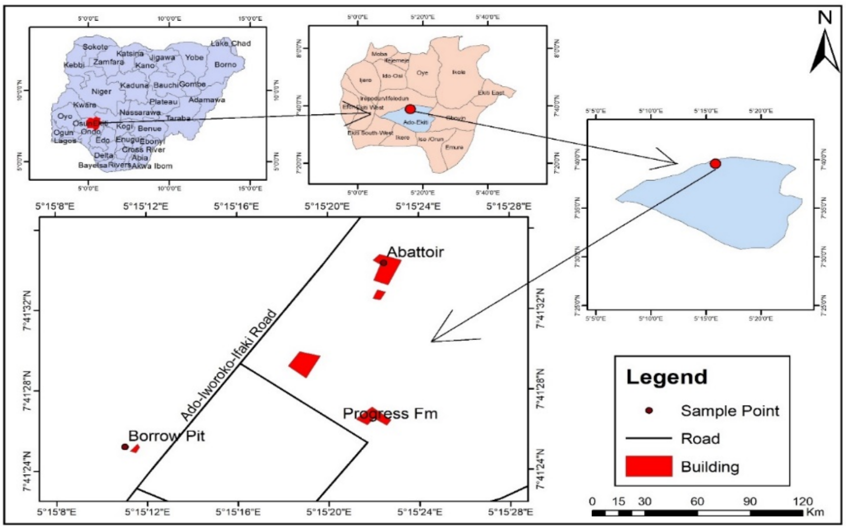


**Fig. 1. Study area map.**

### 2.2. Abattoir wastewater sampling and analytical method

Abattoir wastewater was obtained from the abattoir drains at Ilokun abattoir, Ado-Ekiti. The abattoir wastewater samples were collected into two plastic kegs for physico-chemical tests in the laboratory. The samples were tested fresh and after fermentation of 14 days. They were analysed at the central laboratory of the Federal Polytechnic Ado and chemistry laboratory of Afe Babalola University, Ado-Ekiti. For physical analysis, temperature, colour and conductivity were measured using thermometer, employing Platinum-Cobalt method and conductivity meter respectively in conformity to APHA [18]. Chemical parameters include pH, Total Dissolved Solids (TDS), Chloride, Sulphate, Nitrate, Total Hardness and Heavy metals (Zinc, Cadmium, Copper, Iron, Lead, Nickel and Chromium).

Volumetric analysis as stated by APHA [18] was employed for determining the chemical parameters except for heavy metals which digested specimens (solution of 100ppm of the element) were taken for analysis using Atomic Absorption Spectroscopy (AAS) machine -Agilent 55A, at the Chemistry laboratory, Afe

Babalola University, Ado-Ekiti. The heavy metal analysis was also in accordance with APHA [18].

## 2.3. Soil sampling and analytical method

Disturbed soil samples were taking from a borrow pit at Ilokun, Ado-Ekiti. The samples were air-dried before being used for geotechnical test. Some fractions of the air - dried lateritic sample were contaminated with abattoir wastewater. The lateritic soil samples were contaminated with 5%, 10% and 20% of abattoir wastewater by weight of dry soil. These contaminated samples were left in three (3) plastic containers for 14 days to equilibrate and thereafter air-dried. Uncontaminated/natural and contaminated soil samples were taken to the Soil Mechanics Laboratory of Civil Engineering Department, The Federal Polytechnic Ado-Ekiti for geotechnical tests.

Basic tests including specific gravity, particle size distribution, Atterberg limits (Liquid limit - Cone Penetrometer method, plastic limit and linear shrinkage), compaction, California Bearing Ratio (CBR) and direct shear tests were conducted according to BS 1377 [19] while permeability was conducted using falling head method according to the method described by Das [20]. Specific gravity, particle size distribution and Atterberg limit tests were conducted according to part 2, compaction and CBR were done according to part 4 while direct shear was in conformity to part 7 of BS 1377. Compaction, direct shear and permeability tests were conducted using compaction mould (Controls T0070), Shear tester (Controls T206) and falling head permeability apparatus (Controls Serial no: 91010020) respectively. CBR machine (ELE Serial no: 212060257) and electronic sieve shaker (Endecotts Serial no: 8488) were used for CBR strength and particle size distribution tests. The laboratory summary of sample preparation methods employed is presented in Fig. 2. Oxide's composition of the soil was determined adopting the method described in Annual Book of ASTM Standards [21].

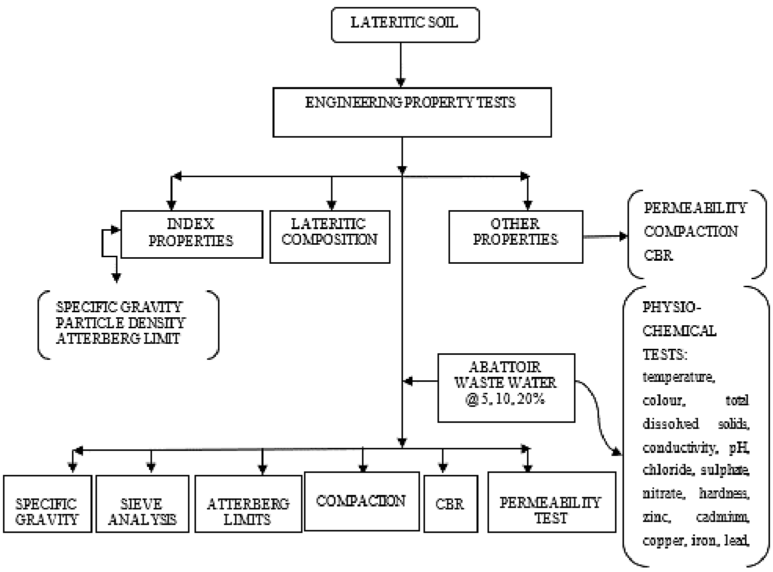


**Fig. 2. Schematic experimental program.**

## 3. Results and Discussion

### 3.1. Abattoir wastewater

Some physical and chemical analysis of the abattoir wastewater sample were carried out. The tests were carried out on the fresh and fermented abattoir wastewater. The concentration values of fresh and fermented abattoir wastewater are shown in Table 1. Except colour, the results of temperature, total dissolved solids, conductivity, and pH for both fresh and fermented contaminants fell within FEPA [22] permissible limit. The concentrations of chloride, sulphate, nitrate and total hardness also fell within the limit.

The concentrations of heavy metals except Zinc and copper are within recommended limit. The results revealed that concentrations of chlorides, zinc, cadmium, copper, lead and chromium decreased with time while other parameters increased with time except nickel and colour that remained constant with time.

**Table 1. Results of physicochemical test of abattoir wastewater.**

| Parameter | Fresh | Fermented | FEPA Limits |
|---|---|---|---|
| **Temperature (ºC)** | 24ºC | 25ºC | <40 |
| **Colour (HU)** | >70 | >70 | 7 |
| **Conductivity(µmho/cm)** | 716 | 719 | 1000 |
| **pH** | 6.41 | 6.46 | 6 - 9 |
| **TDS (ppm)** | 442 | 445 | 2000 |
| **Chloride, (ppm) Cl** | 32.00 | 28.17 | 600 |
| **Sulphate, (ppm) $SO_3$** | 28 | 29 | 500 |
| **Nitrate, (ppm) N** | 6.12 | 6.78 | 20 |
| **Total Hardness (ppm).$CaCO_3$** | 93.00 | 97.40 | 200 |
| **Zinc, (ppm) Zn** | 10.12 | 10.04 | <1 |
| **Cadmium, (ppm) Cd** | 0.12 | 0.11 | <1 |
| **Copper, (ppm) Cu** | 6.75 | 6.71 | <1 |
| **Iron, (ppm) Fe** | 1.82 | 1.92 | 20 |
| **Lead, (ppm) Pb** | 0.14 | 0.13 | <1 |
| **Nickel, (ppm) Ni** | 0.01 | 0.01 | <1 |
| **Chromium, (ppm) Cr** | 0.02 | 0.02 | <1 |

### 3.2. Natural soil properties

Laterite characterization of the natural soil sample was determined while other tests including specific gravity, compaction, Atterberg limit, CBR and direct shear were performed on the uncontaminated/natural and contaminated soil samples. Silica sesquioxide's ratio $\left(\frac{SiO_2}{Fe_2 0_2 + Al_2 O_3}\right)$ of 0.66 was obtained.

This indicates that soil is laterite, since it is lesser than 1.33 [23, 24]. Some oxides composition including silica, alumina and ferric as well as some engineering properties of the soil sample are presented in Tables 2 and 3.

**Table 2. Chemical composition of the soil.**

| Oxide's composition | % |
|---|---|
| **$SiO_2$** | 31.02 |
| **$Al_2O_3$** | 23.17 |
| **$Fe_2O_3$** | 21.18 |
| **CaO** | 0.31 |
| **MgO** | 0.16 |

**Table 3. Some geotechnical test results of natural soils.**

| Properties | Values |
|---|---|
| **Specific Gravity, $G_s$** | 2.51 |
| **Liquid Limit (%)** | 43.00 |
| **Plastic Limit (%)** | 15.73 |
| **Plasticity Index (%)** | 18.27 |
| **Maximum Dry Density, MDD ($kg/m^3$)** | 1905 |
| **Optimum Moisture Content, OMC (%)** | 16.30 |
| **Coefficient of Permeability, k (cm/s)** | $1.93x10^{-3}$ |
| **California Bearing Ratio, CBR (%)** | 23.42 |
| **Cohesion, *C* ($kN/m^2$)** | 17.00 |
| **Angle of internal friction $\varphi$ ($^0$)** | 6.00 |
| **AASHTO Class** | A-7-6 |
| **USCS Class** | CL |

## 3.3. Effect of contamination on soil properties

### 3.3.1. Specific gravity

Figure 3 shows decrease in the specific gravity of the soil samples with increase in abattoir wastewater content. Specific gravity values decreased from 2.51 to 2.04. This behaviour agrees with findings of Khan et al. [25] and Zbar et al. [26] on the effect of effluent contamination on the geotechnical characteristics of cohesive soil and geotechnical properties of compacted silty clay mixed with different sludge contents, respectively.

Reduction in specific gravity can be attributed to increase in lighter weight matter in contaminated soils together with decomposition of soils. Materials with low specific gravity are prone to breaking down and changes in properties with time. The denser the material, the greater the specific gravity because it is a ratio of a solid density to density of water.

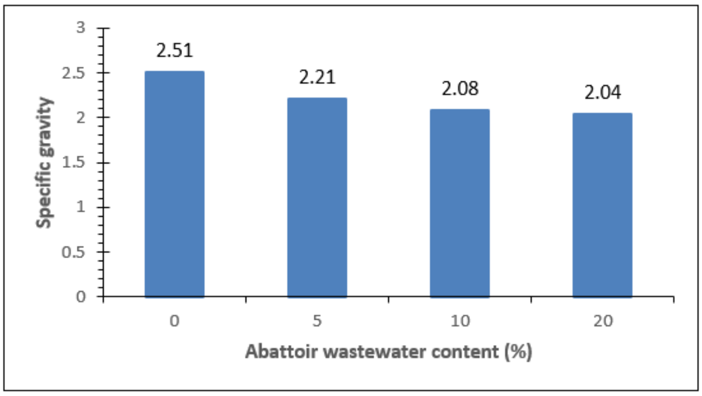


**Fig. 3. Specific gravity behaviour of the soil mixture.**

### 3.3.2. Particle size distribution

The effect of abattoir wastewater is evident on the particle/grain size distribution as depicted in Fig. 4. The percentage finer than sieve no 200(0.075mm) are 59.66, 62.08, 70.76 and 74.78 for control (0%), 5%, 10%, and 20% soil abattoir wastewater content, respectively. The percentage of fines increased with increase in abattoir wastewater content, and it can be linked to disintegration and decomposition of soil grains. This behaviour conforms to the findings of Oluremi et al. [14] in their study on the effect of cassava wastewater on geotechnical properties of lateritic soil.

Chemical concentration may have had major influence on the degradation of soil. Jia and Yang [23] and Jia et al. [27] stated that when a soil mass is influenced by pollutant, the colloids in the soil (organic and inorganic), gets dissolved and results in the weakening of the strong link between the soil grain which will make most of the soil grains disperse easily and clay grain will be increased in heavily polluted soil.

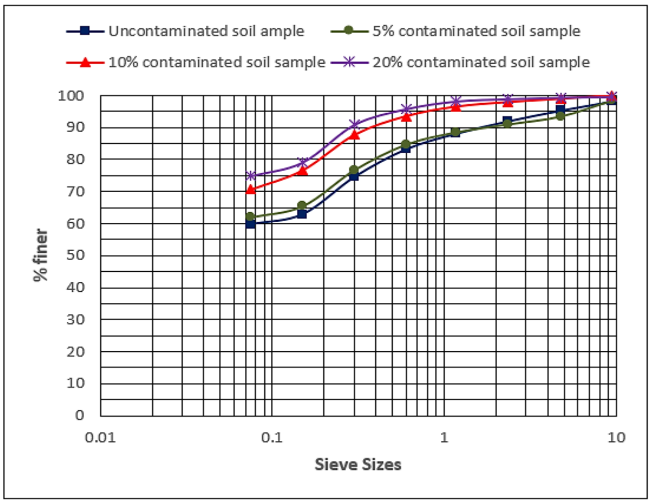


**Fig. 4. Particles size distribution curve of contaminated and uncontaminated soil.**

### 3.3.3. Atterberg limits

The effect of abattoir wastewater content on the Atterberg limits behaviour of the contaminated soil sample is presented in Fig. 5. Increase in abattoir wastewater content caused increase in liquid limit, plastic limit and even the plasticity index. The increase in liquid limit and plastic limit is consistent with the findings of Zbar et al. [26]. The liquid limit values are 43% for uncontaminated, 50%, 68% and 70% at 5%, 10% and 20% contamination respectively while the plasticity exhibited increase at all levels of contamination. The plasticity index values are 18.27% for uncontaminated, 23.7%, 35.57% and 37.57% at 5%, 10% and 20% contamination, respectively. Addition of abattoir wastewater changes the soil sample from Sandy lean clay (CL) to Sandy fat clay (CH) at 5% contamination and Fat clay with sand (CH) at 10% and 20% contaminations, respectively.

Effect of contamination is also observed in the linear shrinkage as every dosage of contamination caused an increase in shrinkage property. This behaviour agrees with the findings of Oluremi et al. [16] and Sunil et al. [28]. While the former studied the effect of leachate contamination on some characteristics of lateritic soil, the latter investigated the effect of cassava wastewater on geotechnical properties of lateritic soil. Increase in index properties together with increase in percentage of fine that has been established from particle size distribution can be linked to decomposition of soil grains to clay. This can be attributed to the high organic matter and viscosity among other characteristics of abattoir wastewater as reported by Nazir [29] that an organic fluid physical property could influence liquid limit. The test result is also consistent with the assertion of Jia and Yang [23] that clay content increases with increase in pollutant.

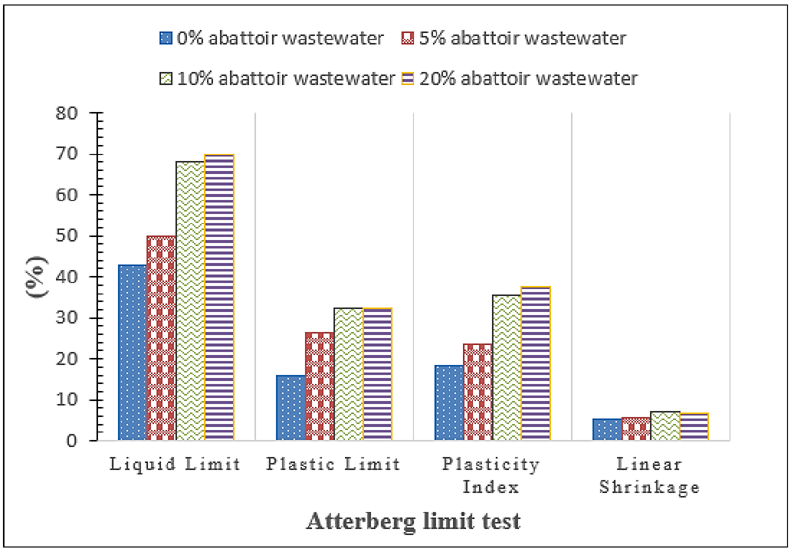


**Fig. 5. Atterberg limits behaviour of soil mixture.**

### 3.3.4. Compaction characteristics

The values of Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) for uncontaminated (0%), 5%, 10% and 20% soil abattoir wastewater are shown in Fig. 6. The Maximum Dry Density decreases with increase in abattoir wastewater. The MDD of the lateritic soil samples are 1905 kg/m$^3$,1745 kg/m$^3$,1441kg/m$^3$ and 1430kg/m$^3$ for uncontaminated sample, 5% contamination,10% contamination, 20% contamination, respectively. OMC increases with increase in contaminant content except from 20% addition. These values are 16.3%, 17.6%, 17.8% and 15.0% for uncontaminated sample, 5% contamination, 10% contamination, 20% contamination, respectively.

This behaviour is consistent with the findings of Oluremi et al. [16] and Oyegbile and Ayininuola [30] but partially agrees with the findings of Khamehchiyan et al. [31] and Zbar et al. [26] as the behaviour of the MDD is consistent with theirs but the OMC is in contrast with their report. Further decomposition of soil grains to clay must be responsible for the lower maximum dry densities. Density affects the strength of the soil and the potential of soil to absorb water at later time decreases due to higher densities. This result can be attributed to the effect caused by chemical reaction (change in the nature of pore fluid) between wastewater and soil.

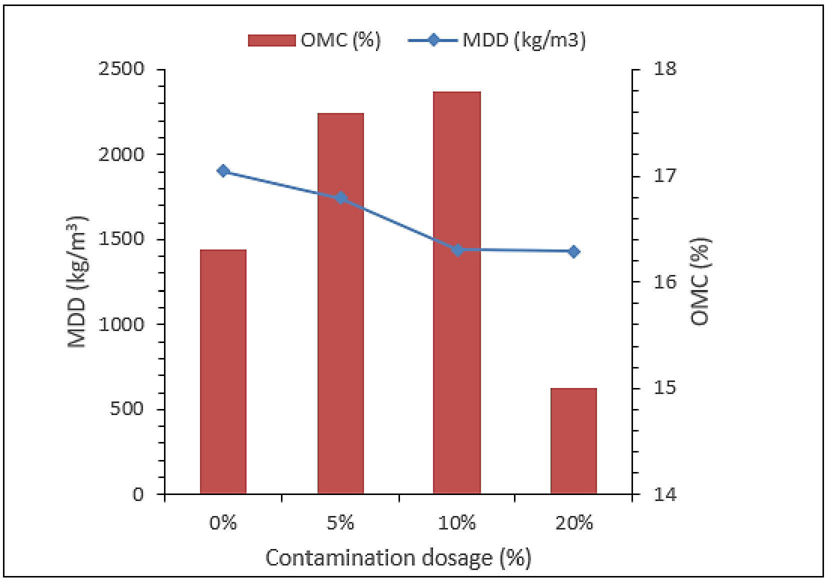


**Fig. 6. Compaction characteristics of the soil mixture.**

### 3.3.5. California Bearing Ratio (CBR)

Figure 7 shows the variation of CBR. values with abattoir wastewater content. Increase in abattoir wastewater content leads to reduction in CBR values for soil contaminated content. CBR measures soil quality and the quality of the soil decreases with increase in contamination content. There was a drop in the strength values from 23.42% at its natural state to 6.14 % (the lowest) when it was contaminated with 20% abattoir wastewater. This may be due to the behaviour of the soil (like a clay material) occasioned by disintegration of the soil particles.

This behaviour will reduce the strength of the soil because of the tendency of clay troublesome nature. This behaviour agrees with the report of Al-Aghbari et al.

[32] and the findings of George et al. [33] on the effect of diesel oil contamination on geotechnical properties of soil but contradicts that of Oluremi et al. [16] which reported slight increase in CBR Values. Although, the CBR value of the last layer of the study showed decrease in CBR value which may be attributed to the fact that the soil at that layer is mostly contaminated owing to heavy concentration and percolation of the cassava wastewater.

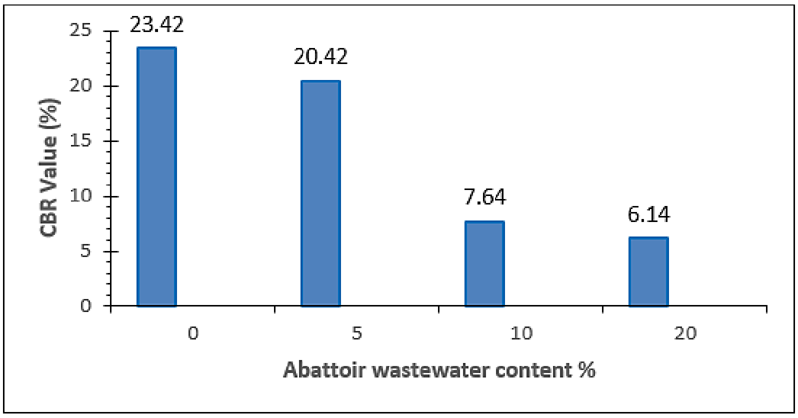


**Fig. 7. CBR behaviour with varying abattoir wastewater content.**

### 3.3.6. Direct shear

Direct shear is used to measure shear strength parameters. As shown in Fig. 8, values of cohesion increase with corresponding increase in abattoir wastewater content while values of angle of internal friction were fluctuating. The abattoir wastewater contaminated soil had the highest cohesion of 110 kN/m$^2$ at 20% contamination while the lowest value of 45 kN/m$^2$ was observed at 5% contamination. This infers that the lower the percentage addition of abattoir wastewater, the lower the cohesive force.

Increase in cohesion is attributable to the transformation of some soil minerals to clay minerals due to decomposition. Increase in value of cohesion with fluctuating value of internal friction may lead to reduction in strength. This agrees with the findings of Sunil et al. [28] that there is slight increase in cohesion and decrease in the frictional angle of a leachate contaminated lateritic soil. The cohesion behaviour of the contaminated lateritic soil also agrees with the report of Al-Aghbari et al. [32] where the addition of diesel and gasoline caused an increase of cohesion of contaminated sands, but the frictional angle results negate their report as there was mostly increment except at 10% contamination which exhibited the same value (6º) with the uncontaminated soil sample.

#### 3.3.7. Permeability

The coefficient of permeability variation is presented in Fig. 9. It was generally observed that permeability decreased very slightly with increase in contaminant content. The coefficient of permeability reduced from $1.93 \times 10^{-3}$ cm/s down to $1.52 \times 10^{-3}$ cm/s. This agrees with the findings of Khan et al. [25] and Rahman et al. [34] in their investigation of geotechnical properties of contaminated soil. The reduction was consistent with subsequent increase in contamination dosage.

This can be linked to further disintegration and transformation of soil grain to clay. The disintegrated particles must have filled certain portion of the voids thereby reducing the coefficient of permeability and making the samples less permeable. Also, the clogging of some inter-particle's spaces by abattoir wastewater oil which will resultantly reduce pore space in the soil and cause increase in bulk densities may be responsible for this drainage behaviour [35].

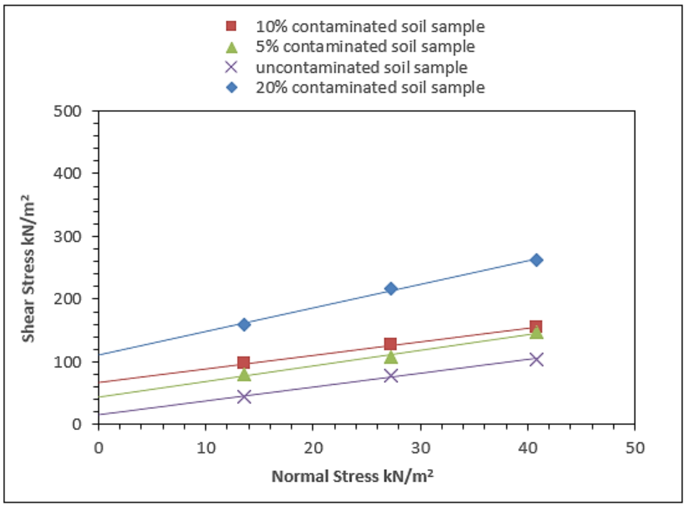


**Fig. 8. Direct shear behaviour of soil contaminated with abattoir wastewater.**

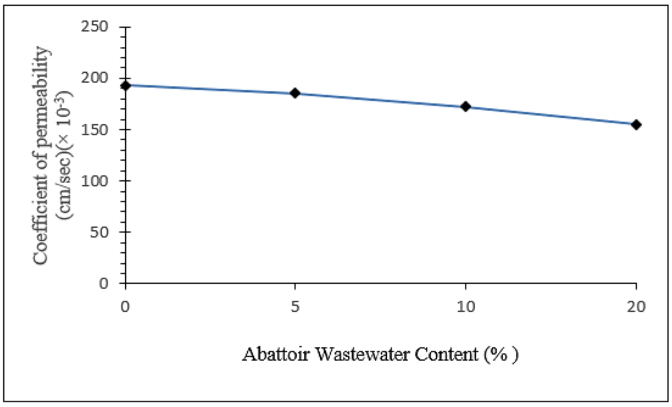


**Fig. 9. Variation of permeability with abattoir wastewater content.**

## 4. Conclusions

This paper has assessed the effect of Ilokun abattoir wastewater on some geotechnical properties of lateritic soil. Laboratory investigations were carried out conducting tests on abattoir wastewater, natural soil and contaminated soil samples. The contamination levels were at 5%, 10% and 20% and from the test results the following can be deduced.

- There was rise in the percentage fines of the soil which makes the soil problematic. There is also observed increase in plasticity index of the soil. On the compaction characteristics of the soil, it reduced the maximum dry density and predominantly increased the optimum moisture content of the soil samples.
- The contamination of the lateritic soil lowers the CBR and frictional angle of the soil while it increases cohesion. Contamination of the lateritic soil also lowers permeability rate of the soil.
- It is evident that the contamination of lateritic soil with abattoir wastewater adversely affect the geotechnical properties of soil.
- This present study infers that indiscriminating disposal of abattoir wastewater should be discouraged while the need to stabilize lateritic soil underlying abattoir yard or site before using it for construction purposes should be emphasized.
- Furthermore, based on the findings of the study, there is a need for long-term evaluation of the effect of abattoir wastewater contamination on the selected soil characteristics as this will allow assessment of geotechnical behaviour with a view of comparing with the presented results.

**Abbreviations**

| | |
|---|---|
| AAS | Atomic Absorption Spectrophotometer |
| AASHTO | American Association of State Highway and Transportation Officials |
| AWW | Abattoir Wastewater |
| BS | British Standard |
| CBR | California Bearing Ratio |
| EDTA | Ethylene Diamine Tetra Acetic Acid |
| FEPA | Federal Environmental Protection Agency |
| TDS | Total Dissolved Solid |
| MDD | Maximum Dry Density |
| OMC | Optimum Moisture Content |
| USCS | Unified Soil Classification System |

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