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EFFECT OF LEAD NITRATES CONTAMINATION ON COMPACTION CHARACTERISTICS OF LATERITIC SOIL

ABDULFATAH A.Y[1]., SANI J E[2], MOSES G[2]., IJIMDIYA T. S[3]. AND KEVIN O. K[4].

[1]Department of Civil Engineering, Bayero University Kano. [2] Department of Civil Engineering, Nigeria Defense Academy, Kaduna, [3]Department of Civil Engineering, Ahmadu Bello University Zaria. [4] Department of Civil Engineering, Air Force Institute of Technology, Kaduna

Abstract

Heavy metal contamination alters the physical, chemical, and geotechnical properties of soil. A laboratory test was carried out to determine the effect of lead nitrate contamination on the compaction characteristics of lateritic soils. Compaction tests were carried out on both natural and lead nitrate-contaminated soil samples at British Standard light (BSL), West African Standard (WAS) and British Standard Heavy (BSH) compaction energies. Contaminated soil specimens were prepared by mixing the lateritic soil with a maximum 1% lead nitrate concentration at a stepwise of 0.2% by weight of dry soil. The results obtained show that with an increase in the percentage of lead nitrate, maximum dry density for the various compactive effort increase while the optimum moisture content decrease, consequently, as the lead concentration increases there is an increase in maximum dry density with the peak at 0.6% and thereafter there was a reduction, and the maximum dry density value increases from a natural value of 1.68, 1.76, and 1.84 Mg/m^3 to 1.89, 1.90, and 2.0 Mg/m^3 at 6% lead concentration for BSL, WAS and BSH respectively, Therefore, contaminated lateritic soil will need more compactive effort to set the desired maximum density if used as a hydraulic barrier.

Keywords: *Lead nitrate, contamination, compactive effort, compaction, maximum dry density*

Introduction

Land contamination can result from intended, accidental, naturally occurring activities, manufacturing, mineral extraction, leaking underground storage tanks, illegal waste disposal, and so on. The effects of these activities have caused the leaching of the toxic chemical into the nearby ground or surface water, change in climate pattern or surface water, and ecology of the environment.

Aside from the environmental impact of pollution or contamination of soils, their physical, chemical, and mechanical properties can be altered when contaminated with heavy metals. Soil contamination by heavy metals especially Lead (Pb) has been reported in the Northern, West, and Central part of Nigeria in 2010. The epidemic left 400 children (< 6 years) dead and about 3500 children seriously sick (WHO 2011). Many researchers have investigated the effects of crude oil on soils (Sahel, (2007), Ijimdiya, (2007) and 2013), Khamehchiyan *et al.,* (2007), and Rahman *et al.*, (2011)

The presence of inorganic salt reduces the liquid and plastic limit of soils (Ayininola and Agbede 2013), and (Arasan et al 2007) but in the studies made by (Arasan and Yetimoglu 2008) and (Khalid and Basn 2017) they found out that both the liquid limit and plastic limit increased when the concentration of the salt solution was increased, and the maximum dry density was lower with higher optimum moisture content.

The effect of surfactant as soil contaminant has been studied by Park et al (2006), they discovered that the maximum dry unit weight and optimum moisture content increase also electrolyte solution like $CaCl_3$ and $NaPO_3$ decreases the optimum moisture and increase the maximum dry density.

Resmi et al., (2011) and Mahdi & Shahad 2020 studied the effect of lead on clayed soil with emphasis on hydraulic conductivity, coefficient of consolidation, and shear strength parameters. While Umesha et al. (2021) work on the effects of hydrochloric, phosphoric, and sulphuric acids on the compaction characteristics of black cotton soil at a different percentage. The results showed that acid contamination mixed with soil has adverse effects on the geotechnical properties of soil.

There have been a few studies on the effect of lead nitrates on lateritic soils with an emphasis on compactive efforts at desired moulding moisture content.

The compaction properties of soil are very important as they determine the suitability of soil for various construction purposes such as roads, embankment dams, land fillers, and foundations.

Lateritic soils have been used successfully in the construction of dams and embankments where strength and compressibility are of primary concern, they have not been used as a hydraulic barrier in waste containment facilities (Osinibi 2006).

Consequently, this study investigates the effect of lead nitrates contamination on compaction characteristics of lateritic soil while considering their use as a hydraulic barrier.

Materials and Methods of testing soil

The soil sample used for this study is natural reddish-brown laterite taken from a burrow pit at Shika in Zaria (lat. 11^0 15'N & long. 7^0& 45^0 E) or 0344054N and 1238202E UTM Co-ordinates obtained using a global positioning system (GPS). It was collected as a disturbed sample obtained at a depth of 0.5m below the ground surface.

Soil sample for natural moisture content determination was stored in a watertight container while that of other laboratory tests were stored in sacks before they were transported to the laboratory. In the laboratory, the soil sample was air-dried and passed through a 4.75mm sieve.

Reagent:

The Lead nitrate $(Pb(N0_3)_2$ is 99% in purity, obtained from Loba Chemie PVT. Ltd. It has a density of 4.53g/cm^3, solubility in water of 565g/l and a molar weight of 331.2g/mol. Standard ASTM Type 1 deionized water was used throughout this experiment.

Artificial Contamination of Soil Samples

Three amounts of soil (each part weighing 15kg) were put in three separate plastic containers. The soil sample in each bucket was thoroughly mixed with lead nitrate at the stepwise concentration of 0.2% in the range of 0-1.0% with the respectively dry weight of the soil sample. The mixture was then left for a month to achieve a lead nitrate saturated homogeneous mixture as in the line with Resmi, et al. (2011) and Karkush, et al (2013). After 30 days the contaminated soil samples were taken out of the solution. These were stirred with a mixer for 15 minutes to allow the lead nitrate to be evenly distributed in the soil. (Gadget al 2021). The soil was then dried at room temperature, pulverize, pass through a 2mmsieve, and then stored in polyethene bags for later used.

Compaction.

Three compaction efforts namely British Standard Light (BSL), British Standard heavy (BSH), and the West African standard (WAS) or intermediate were used.

The BS compaction is equivalent to the standard proctor, while the BSH compaction is the equivalent of the modified proctor compaction. The WAS or intermediate compaction is the conventional energy level commonly used in the region. (Osinubi 1998).
A comparison of the three-compaction effort is given in Table1. Soil specimens were prepared to cover a wide range of moulding moisture (-2, 0, and +2) content extending beyond the plastic limits of the soil.

Table 1: Comparison of compaction test procedures (Source Osinubi 1998)

Test Procedure	*Width of rammer(kg)*	*Height of fall (m)*	*Number of blows per layer*	*Number of layers*	*Compaction energy KNm/m^3*
BS Light compaction	2.5	0.3048	27	3	605.9
West African Standard Compaction	4.5	0.457	10	5	1008.7
B.S Heavy Compaction	4.5	0.457	27	5	2723.5

Discussion of Results

A summary of the engineering properties of the soil sample is shown in Table 1. The soil is classified as clay of low plasticity (CL) in accordance with the Unified Soil Classification System (USCS). The high values of the Atterberg limits (linear shrinkage, plasticity index, plastic limit, and liquid limit) are 5.6%, 28.12%, 15.38%, and 43.5% respectively for the natural soil
A summary of the properties of the natural soil is given in table 1.

Table2: Geotechnical properties of the natural soil

Properties	*Value/Description*
%Passing B.S Sieve No 200	82.15
Liquid limit (LL)%	43.5
Plastic limit (PL)%	15.38
Liner Shrinkage%	5.6
AASH to classification	A-7-6
Unified soil classification System (USCS)	CL
Plastic index	28.12
Group index	15

Specific gravity	2.67
Natural moisture content %	22.7
Colour	Reddish brown
Sand (0.0075mm-4.75mm)	25.45
Clay (< 0.002mm	82.18
PH	6.8

The chemical composition of the soil determined using the XRF spectroscopy at the Federal Ministry of Agriculture Kaduna is summarized in Table 2. The major oxide present in the soil is silicon oxide (S_iO_2), (52.31%) iron oxide (Fe_2O_3), 44.5% potassium oxide(K_2O) 0.53% titanium trioxide (Ti_2O_3) and Aluminum oxide (Al_2O_3)33%.

Table3: Oxide composition of Natural Lateritic soil.

Oxide	*Concentration %*
SiO_2	52.309
V_2O_5	0.081
Cr_2O_3	0.004
MnO	0.084
Fe_2O_3	11.499
CO_3V_4	0.054
CU	0.043
Nb_2O_3	0.017
$M00_3$	0.004
Cao	0.049
K_2O	0.527
B_aO	0.014
Al_2O_3	32.99
Ta_2O_5	0.028
TiO_2	1.502
ZnO	0.002
Ag_2O	0.014
CL	0.65
ZrO_2	0.157

The silica sesquioxide molar ratio of iron and aluminium was obtained by dividing the percentage of silicon oxide (SiO_2) by the summation of the percentage of iron oxide (Fe_2O_3) and Aluminum oxide (Al_2O_3) which is 1.18 which indicates that the soil is lateritic. Lateritic soils can be distinguished from other soil types based on the ratios of silica (SiO_2) to sesquioxide (Fe_2O_2, Al_2O_3). In laterite, the ratio is less than 1.33. Those between 1.33 and 2.0 are termed lateritic and if the ratio is greater than 2.0 indicates other types of tropical soils. (Blight 1997).

Compaction characteristics

Figures 1-6 shows the relationship between dry density and moisture content concerning different energy levels and different percentage of lead contaminants. Figure one shows zero per cent (0%) of the contaminant of the lateritic soil. Figures 2-6 show contamination of the lateritic soil with lead from 0.2% to 1%.

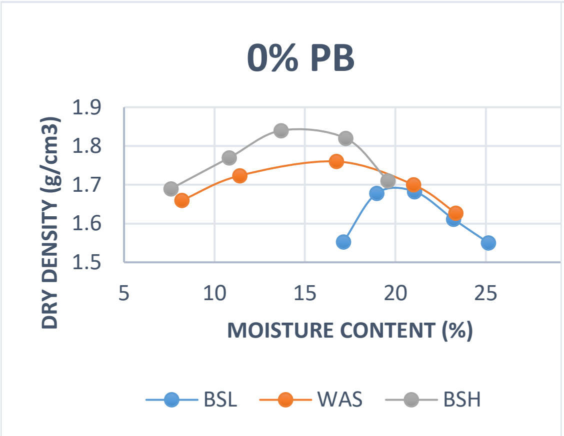


Figure 1: Dry density vs moisture content (0%) contamination.

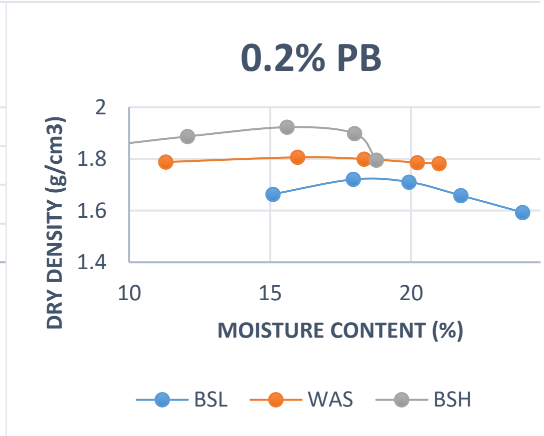
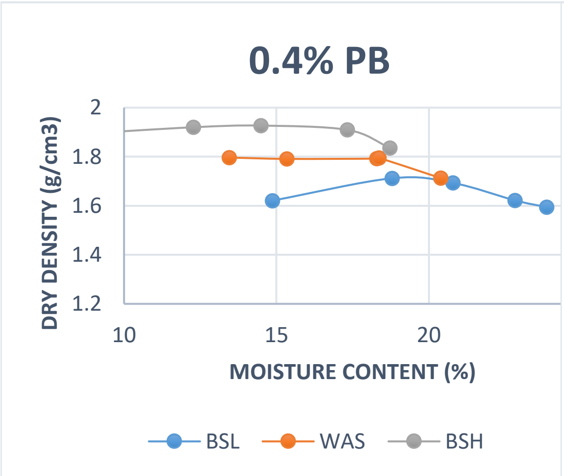


Figure 2: Dry density vs moisture content (0.2%) contamination.



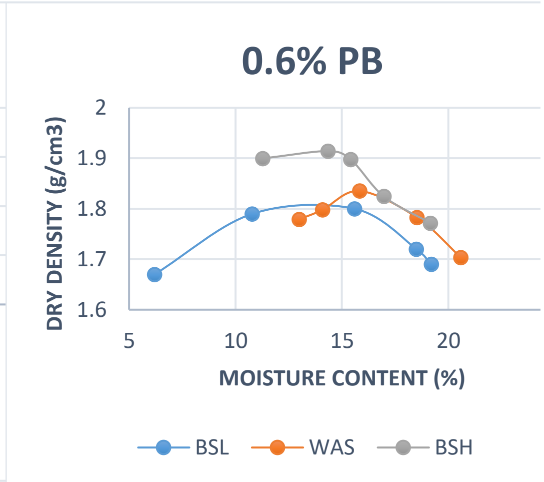


Figure 3: Dry density vs moisture content (0.4%) contamination.

Figure 4: Dry density vs moisture content (0.6%) contamination.

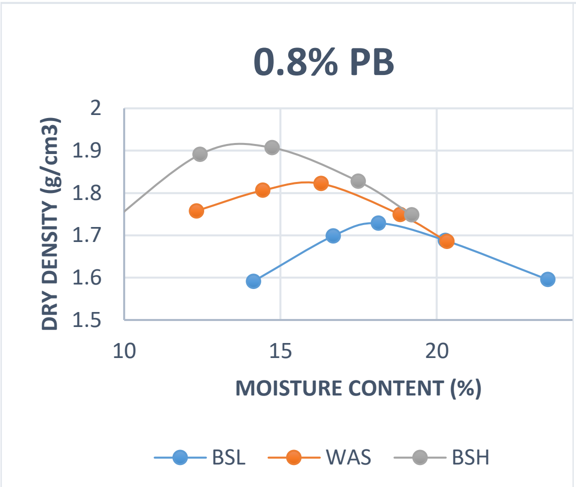


Figure 5: Dry density vs moisture content (0.8%) contamination.

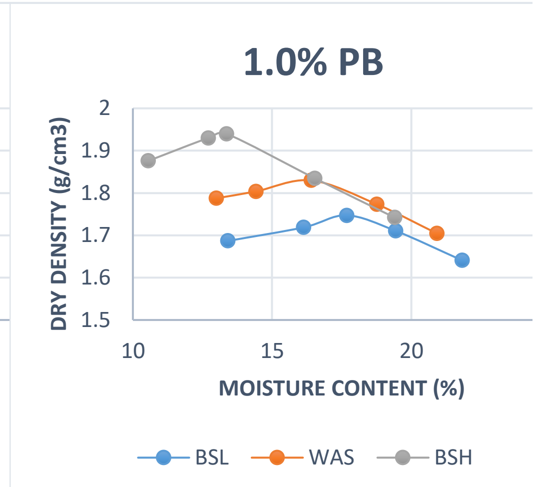


Figure 6: Dry density vs moisture content (1%) contamination.

The results of compaction tests are presented in Figure 7. Values of optimum water content vary from 19-18.8%, 16.8-15.8%, and 14-14.8% for BSL, WAS, and BSH compactive effort respectively.

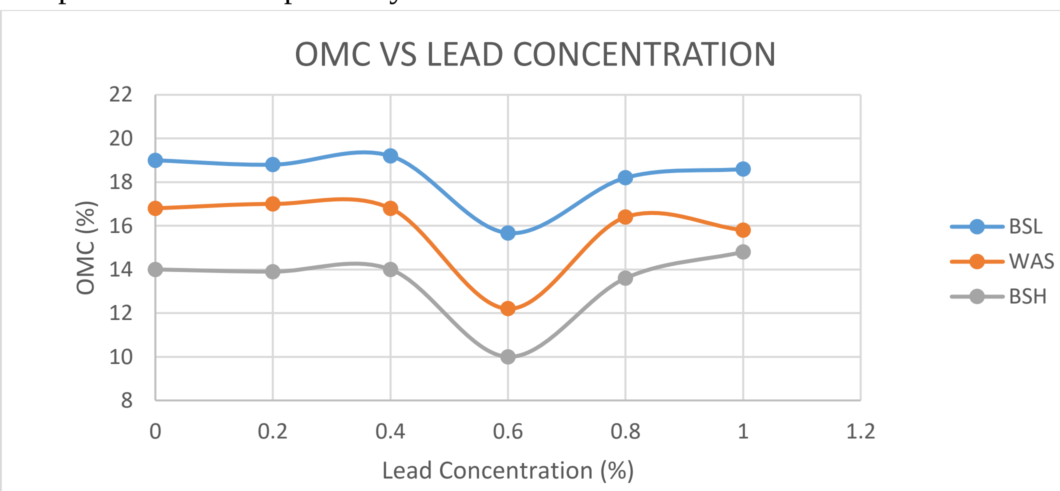


Figure 7: Variation of lead concentration with optimum moisture content at different compactive efforts.

The maximum dry unit weight value ranges from 1.68 – 1.70KN/M^3 for BSL, 1.76 – 1.84 KN/lm^2 for WAS and 1.84 – 1.95KN/m for BSH compacting effort as shown in Figure 8.

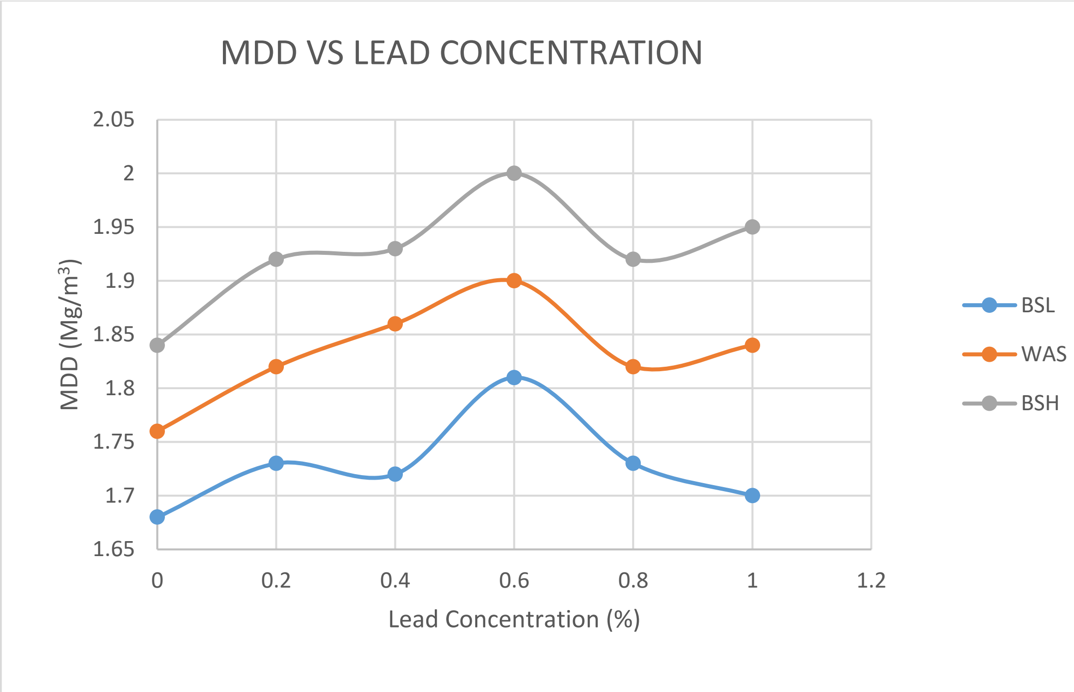


Figure 8: Variation of lead concentration with maximum dry density at different compactive efforts.

Irrespective of the lead concentration the maximum dry density increases with the various compactive effort, consequently as the lead concentration increases there is an increase in maximum dry density with the peak at 0.6% and thereafter there was a reduction, and the maximum dry density value increases from a natural value of 1.68, 1.76, and 1.84 Mg/m^{3}to 1.89, 1.90, and 2.0 Mg/m^3 at 6% lead concentration for BSL, WAS and BSH respectively. The increase is a result of the lead having a higher specific gravity of 4.53g/cm^{3}than the natural soil of 2.67 mg/m^3 and also the contact points on the clay molecules when covered by lead nitrate salt, engineering performance of the soil and the ability of clay to dissociating water molecules is decreased.

Increasing contamination causes a clear change in the compaction curves shape, so as the contamination increase the optimum moisture content reduces this could be a result of a reduction of the voids among the particles due to sedimentation of salts in pores.

The reduction in optimum moisture content causes an increase in the maximum dry density. This finding is similar to the work of (Mahdised and Shadach 2020) and (Sunit et al 2008) and also confirms the classical theory of soil mechanics the higher the optimum moisture content the lower the maximum dry density.
The contamination of lateritic soil with heavy metal will need more compaction effort to get the desired maximum density if to be used as a hydraulic barrier (Ugwu et al, 2018).

Conclusion

The purpose of this work has been to investigate the effect of lead nitrate contamination on the compaction characteristics of lateritic soil. An extensive laboratory testing program was carried out to achieve this objective to vary the degree of contamination the amount of lead nitrate salt mixed with the soil by weight was varied up to 1%. The following was concluded the experimental result indicates that with the increase in the percentage of lead nitrate, maximum dry density for the various compactive effort as the level of concentration increases and in the same vein the optimum moisture content decreases with each of the compactive efforts as the lead nitrate concentration increase with a density with the peak at 0.6% and thereafter there was a reduction, and the maximum dry density value increases from a natural value of 1.68, 1.76, and 1.84 Mg/$m^3$to 1.89, 1.90, and 2.0 Mg/m^3 at 6% lead concentration for BSL, WAS and BSH respectively, before an increase in the maximum dry density. In summary, the results show that contaminated lateritic soil with heavy metal will need more compaction effort to get the desired maximum density

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