LIME TREATMENT OF DIESEL CONTAMINATED TROPICAL LATERITES FOR GEOTECHNICAL APPLICATIONS.

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Abstract

This study investigates the reuse of diesel-contaminated soils in engineering, emphasizing the role of lime treatment to enhance their properties for geotechnical applications. The research aligns with new policies promoting the repurposing of contaminated materials. It specifically examines the effects of diesel contamination on lateritic soil and evaluates lime's effectiveness in restoring its properties.

Laboratory tests were conducted on both natural and diesel-contaminated soils with varying diesel percentages (3%, 6%, 9%, and 12%). The tests included Atterberg limits, compaction, unconfined compressive strength (UCS), and California Bearing Ratio (CBR). Lime treatment was applied to soils with 12% diesel contamination at different lime percentages (3%, 6%, and 9%).

The results showed significant impacts of diesel on the soil's plasticity and strength. For instance, at 12% diesel contamination, the maximum dry unit weight decreased from 19.1 kN/m^3 to 17.65 kN/m^3, while the optimum moisture content increased from 9.8% to 14.4%. Conversely, applying 9% lime treatment improved the maximum dry unit weight to 18.75 kN/m^3 and reduced the optimum moisture content back to 9.8%. Additionally, the Atterberg limits indicated an increase in liquid limit from 31.3% to 43.29% and a rise in plasticity index from 12.44 to 22.4%. The CBR value also improved from 4.52% to 6.24% with lime treatment. Overall, the study concludes that lime treatment effectively enhances the mechanical properties of oil-contaminated soils, making them suitable for reuse in geotechnical applications after adequate curing periods. This suggests a promising approach for addressing soil contamination issues while supporting sustainable engineering practices

Introductions

Soil contamination from petroleum products poses significant environmental and health risks by disrupting soil structure and biodegradability. This contamination arises from multiple sources, including oil spills from warfare, accidents, drilling, and storage facilities. Notable incidents, such as the Gulf War oil spills and ongoing issues in the Niger Delta, have highlighted the pervasive nature of this problem. Contaminated soils exhibit altered physical and chemical properties, such as changes in moisture levels, hydraulic conductivity, and nutrient availability, which adversely affect plant growth and microbial activity.

Ijimdiya (2012) investigated the influence of oil contamination on the aggregate size distribution of soil. The soil, identified as reddish-brown, was obtained from a borrow pit in Shika, Zaria, Nigeria, and primarily consisted of kaolinite clay mineral with 87% silt content. Different concentrations of oil (1%, 2%, 3%, 4%, 5%, and 6% by weight) were blended with the dry soil sample. The contaminated soil was subsequently sieved through mesh sizes ranging from 2.4 mm to 0.075 mm, and the percentage of soil passing through each sieve was recorded to assess the aggregate size distribution. The resulting aggregate size distribution curves indicated a transition from finer to coarser aggregates as the oil contamination increased from 0% to 6% by dry weight of the soil.

Khosravi et al. (2013) studied the effect of oil contamination on Atterberg limits by introducing oil contents of 2%, 4%, 6%, 12%, and 16% by dry weight into a low plasticity clay containing kaolinite. They found that the liquid limit and plasticity index increased as the oil content rose from 0% to 12%. However, a decrease in these parameters was observed when oil content increased from 12% to 16%, as the oil diminished soil cohesion. Kermani et al. (2012) observed that in lean clay, as oil content increased, the plastic limit increased significantly, the liquid limit showed a slight increase, and the plasticity index decreased. This phenomenon occurs because crude oil coats clay particles, hindering water molecules from reaching the double-layer water, thus necessitating more water for the soil to attain plastic properties. If the oil aligns the soil particles, much of the added water during testing will contribute to the free water layer. Consequently, since the flow characteristics of clay depend on free water, no substantial increase in the liquid limit is noted. Therefore, if most added water reaches the free water rather than the double-layer water, the minimal difference between the liquid limit and plastic limit, along with the small plasticity index, is justifiable.

Khosravi *et al.* (2013) examined the effect of oil contamination on Atterberg limits by contaminating a low plasticity clay containing kaolinite with oil contents of 2%, 4%, 6%, 12%, and 16% by dry weight of the soil. They found that the liquid limit and plasticity index increased as the oil content in the soil increased from 0% to 12%. However, there was a reduction in these parameters when the oil content increased from 12% to 16%, as the oil reduced the cohesion of the soil.

Kermani *et al*. (2012) studied lean clay and observed that as oil content increased, the plastic limit distinctly increased, the liquid limit increased slightly, and the plasticity index decreased. This is because crude oil coats clay particles, preventing water molecules from reaching the double-layer water, thus requiring more water for the soil to achieve plastic properties. If the oil aligns the soil particles, most of the added water during testing will join the free water layer. Since the flow characteristics of clay depend on free water, no significant increase in the liquid limit is observed

Akinwumi *et al*. (2014) observed that the optimum moisture content (OMC) decreased as the crude oil content in the soil increased. Since crude oil is hydrophobic, it forms a coating around individual clay particles, preventing free water from interacting with them. This reduction in water interaction likely accounts for the decreased amount of water needed by the soil to reach its maximum unit weight

Rehman *et al.* (2007) examined the compaction characteristics of oil-contaminated high plasticity clay using the standard Proctor compaction test. The study found that the contaminated soil, though the specific oil content was not mentioned, exhibited a higher maximum dry density at a lower optimum water content due to the lubricating effect of the oil on the soil aggregates.

Rahman *et al.* (2011) investigated the compaction characteristics of oil-contaminated metasedimentary soils (silty clay loam) using the standard Proctor compaction test. Generally, oil contamination increased the maximum dry density and reduced the optimum water content. The oil acted as a binding agent for the soil aggregates, particularly as the oil content increased from 0 to 12%. However, at 16% oil content, the maximum dry density decreased due to the excess oil causing the separation of soil voids.

Al-Sanad *et al.* (1995) studied the effect of oil contamination on poorly graded sand, using soil mixed with 2%, 4%, and 6% oil content by dry weight and compacted with a 4.5 kg rammer. This compaction method results in greater soil densification than the standard Proctor test using a 2.5 kg rammer. The study observed a decrease in maximum dry density as the oil content increased from 2% to 6%, attributed to excessive lubrication. However, an increase in maximum dry density was noted from 0% to 2% oil content due to the oil adding cohesion to the soil. Beyond 2%, the oil provided less cohesion, resulting in a reduced maximum dry density.

Khamehchiyan *et al*. (2007) investigated the impact of crude oil contamination on the compaction characteristics of Bushehr coastal soils in Iran, including poorly graded sand, sand with 5-15% silt, and low plasticity clay. The soils were mixed with 0%, 4%, 8%, 12%, and 16% oil by dry weight and compacted using standard Proctor compaction tests. The study confirmed a decrease in maximum dry density with increased oil content, particularly pronounced in sand with 5-15% silt and low plasticity clay. Poorly graded sand exhibited a smaller decrease due to its larger pore spaces allowing easier oil movement. In contrast, the sand with 5-15% silt, having fewer pore spaces, experienced greater lubrication and a consequent decrease in maximum dry density. Low plasticity clay, with even smaller particles, showed a reduction in maximum dry density and optimum water content as oil content increased, as the oil separated the soil voids.

Iloeje and Aniago (2016) reported that petroleum significantly alters the permeability of soils, transforming them from a silty clay state to a more clay-like state, with permeability decreasing drastically as oil content increased by 8%. Petroleum also substantially affects the density of soil samples (Shah *et al*., 2003; Khamechiyan *et al.*, 2007; Yazdi and Teshnizi, 2021), affirming the negative impact of oil on the engineering properties of soils. Khamechiyan *et al*. (2007)

Rahman *et al.* (2007) observed that the permeability of weathered basaltic soil decreased as the oil content increased. This reduction in permeability was likely due to the clogging of inter-particle spaces by the oil, which reduced the available spaces for water seepage. Chang *et al.* (2011) noted that as oil occupies some pore spaces, permeability is expected to decrease with increasing oil content. Similarly, Akinwumi *et al.* (2014) found that increased crude oil content led to a decrease in soil permeability. The crude oil becomes trapped in the pore spaces that form pathways for water, consequently reducing the pore sizes. The overall decrease in permeability of the contaminated soil is thus attributed to the reduction in pore space. The permeability coefficient of sandy soil under severe oil contamination, attributing it to a decrease in void sizes caused by excess oil in the soil. The decline in soil permeability can be linked to the clogging of soil voids, initiated by petroleum contamination (Akpokodje and Uguru, 2019)

Shin and Das (2000), the hydraulic conductivity of soils impacted by oil spills tends to decline continuously and in direct proportion to the concentration of crude oil in the soil samples. Rojas *et al*. (2003) also investigated the influence of petroleum on soils' kinematic viscosity and hydraulic conductivity, a decline in hydraulic conductivity as petroleum quantity increased. They observed that oil-contaminated soils exhibited higher kinematic viscosities. Similarly, Chew and Lee (2006) examined the impact of organic oil spills on the hydraulic conductivity of coarse-grained soils and reported a decrease in hydraulic conductivity with increasing oil content. This decrease was attributed to the occupation of soil voids by the organic oil, which hindered the free flow of water within the soils.

Nazir (2011) observed an increase in clay permeability due to motor oil contamination. This change is linked to the low dielectric constant of motor oil, which affects the thickness of the double-layer in clay. According to double-layer theory, a decrease in the dielectric constant of the pore fluid reduces the double-layer thickness, thereby increasing clay permeability (Mitchell 1993).

Consequently, as crude oil is added to the soil, the double-layer thickness of the clay decreases, and the amount of free water increases (Safehian, Rajabi, and Ghasemzadeh 2018). This increase in clay permeability consequently enhances the permeability of the clayey sand sample, a reasonable outcome given the conditions. In clayey soils, petroleum pollution leads to a reduction in double-layer thickness and an increase in the volume of free water (Safehian *et al*., 2018; Ostovar *et al*., 2020).

Iloeje and Aniago (2016) observed a transition in soil permeability from silty clay to clayey soil as petroleum content increased by 8%, resulting in a drastic decrease in permeability.

In permeability tests with a constant head on three types of sandy soils, the permeability coefficients with varying crude oil content. The data indicate that with increasing crude oil content, the permeability coefficient of; poorly graded soil containing silt less than 15% by weight, well graded soil containing silt less than 15% by weight, and silt sand containing 15% of silt by weight samples initially increases and then decreases.(Mojtaba Ostovar *et al* 2020)This initial increase can be explained by the lubrication of the pores and soil particles by the crude oil, facilitating water passage through the contaminated soil's porous media. However, as the crude oil content continues to rise, it begins to block the soil pores, ultimately reducing permeability (Al-Sanad, Eid, and Ismael 1995; Chew and Lee 2010; Nazari Heris *et al.* 2020).

The engineering properties of oil-contaminated soils are critical for assessing their potential reuse in construction. Traditional remediation methods, such as excavation, have become less favored due to high costs and landfill shortages. Instead, in situ treatment methods, bioremediation using hydrocarbon-degrading bacteria, and phytoremediation employing specific plant species have gained attention for their cost-effectiveness and environmental benefits. However, the effectiveness of these methods can be influenced by factors such as soil type, contamination level, and the specific remediation technique employed.

Research has increasingly focused on stabilizing contaminated soils to restore their engineering properties. Stabilizers like lime, cement, and fly ash have shown promise in enhancing the strength and reducing the plasticity of diesel-contaminated soils. Lime stabilization, in particular, has demonstrated effectiveness in improving soil structure and facilitating particle cohesion. While current studies provide a solid foundation for understanding these remediation techniques, there remains a need for further research into the long-term performance of treated soils and the environmental implications of using lime and other stabilizers in contaminated sites. Addressing these gaps will be essential for developing effective and sustainable remediation strategies.

Material and Methods

Soil

The soil was collected from Nibo- Awka laterite mine which at a bearing of 6°10′N 7°04′E. The soil samples were meticulously stored in airtight containers. Following the removal of stones and plant roots, the soils were sun-dried for approximately two days under ambient conditions. Subsequently, some samples were oven-dried for three days at 60°C. The pulverized, oven-dried soils were then sieved through a 2mm sieve in preparation for further laboratory tests, including Atterberg limits, specific gravity, natural moisture content, sieve analysis, and compaction tests.

Diesel and Lime

The diesel oil utilized in this study as the organic contaminant is commercially available diesel oil. The diesel used in this study was purchased from Ibex filling station Awka. The diesel properties includes; density of 0.53g/cm^3, specific gravity of 0.712, viscosity of 119.70mpa.s flash point of 122℃ phosphorus content 3.93mg/l, calcium content of 7.55mg/l and iron 1.22mg/l.

The lime used in this study is quicklime (CaO). It was purchase form Onitsha market Anambra, Nigeria. The physicochemical properties of the lime. These results indicate that the lime used in this study contains a significant amount of quicklime (CaO), confirming the high purity of the tested lime.

Table 1 physical properties of natural soil

Parameters	**Values**
D_{10}	0
D_{30}	0.2
D_{60}	0.34
Coefficient of Uniformity (C_u)	0
Coefficient of Curvature (C_c)	0
Percentage Passing Sieve No 200 (0.075mm)	25.28
Fine Content (%)	25.28
Sand Content (%)	74.62
Specific gravity	2.55
Liquid limit (%)	31.3
Plastic limit (%)	18.86
Plastic index (%)	12.44
AASHTO Soil Classification System	A-2-6(0)
USCS Equivalent	SM (Silty Sand)

Table 2 Chemical properties of natural soil

Parameters	**Values**
Electrical Conductivity (µscm-1)	924
Organic Carbon (%)	1.19
Organic Matter (%)	2.05
Exchange acidity (Meq/100g)	6.00
Exchange bases (Meq/100g)	14.10
Soil pH	11.20
Cation Exchange Capacity (Meq/100g)	20.10

Preparation of contaminated soil and lime treated soil sample

In this study, diesel oil was directly combined with dry soil to create samples of oil-contaminated soil. Various ratios of diesel to dry soil were established at 3%, 6%, 9%, and 12% to simulate different levels of contamination. During the preparation of the samples, the soil was air-dried for 96 hours and thoroughly mixed to achieve homogeneous mixtures, subsequently allowing for a period of 48 hours to ensure complete saturation. Changes in the final oil content due to evaporation were not taken into account in this research. To evaluate the impact of lime treatment on diesel-contaminated soil, a diesel-to-dry-soil ratio of 12% was selected. Lime treatment was then applied to the dry weight of the 12% diesel-contaminated soils at concentrations of 3%, 6%, and 9%.

Result

Effect of diesel contamination on soil properties

Atterberg limit

The Atterberg limits serve as indicators of the physicochemical transformations occurring in soil. Figure 1.1 depicts the influence of diesel concentration on the Liquid Limit (LL), Plasticity Limit (PL), and Plasticity Index (PI) of the soil. Specifically, the introduction of diesel results in an elevation of the soil's LL. Correspondingly, the PL values also increase with additional diesel. Consequently, the PI of diesel-affected soil rises as diesel content escalates. Kermani and Ebadi

(2012) similarly reported that silt soil contaminated with crude oil exhibited heightened plasticity and liquid limits correlating with increased oil concentrations. This phenomenon is attributed to the interactions between soil particles and water in the presence of oil. Likewise, Akinwumi *et al.* (2014) found that the liquid limit of lateritic soil increased upon diesel oil contamination, underscoring the significant effects of hydrocarbon pollutants on the consistency limits of soil. The underlying mechanism involves diesel hydrocarbons adsorbing onto soil particle surfaces, which modifies particle arrangement and amplifies repulsive forces. This interaction enhances water absorption capacity, thereby increasing the liquid limit. Additionally, diesel contamination diminishes cohesion among soil particles, rendering the soil more prone to flow under lower stress conditions, further contributing to the rise in liquid limit.

The plastic limit can also be influenced by diesel contamination due to alterations in the microstructure of the soil upon exposure to diesel. The plastic limit increases progressively with higher diesel content, mirroring the trend observed in the liquid limit. Ng et al. (2006) corroborated this observation. The plasticity index, which is dependent on both liquid and plastic limits, experiences a slight increase as both limits rise with increasing diesel concentration. Thus, plasticity escalates alongside diesel content.

Overall, diesel contamination leads to an augmentation in both the liquid limit and plasticity index of soil, while exerting minimal effects on the plastic limit itself. These alterations highlight the modified consistency limits of diesel-contaminated soil, potentially impacting its engineering properties and suitability for construction applications. Understanding these effects is essential for devising effective remediation strategies and evaluating the usability of contaminated soils.

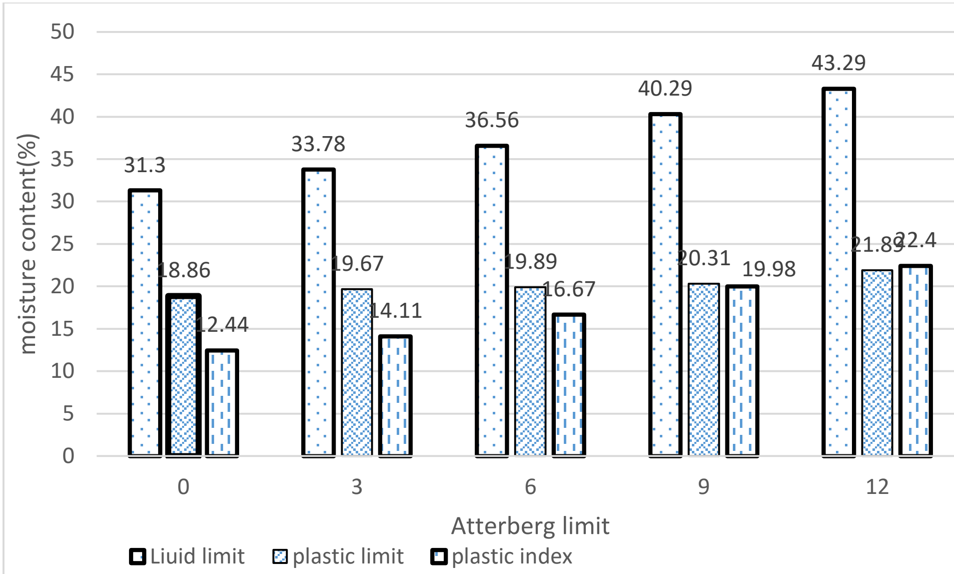


Figure 1: Atterberg limit result of diesel contaminated soil

Compaction parameters

The influence of diesel contamination on compaction parameters, including optimum moisture content and dry unit weight, is significant. These properties play a crucial role in determining the stability and load-bearing capacity of soil. The presence of diesel oil can modify these characteristics, thereby affecting the soil's suitability for construction and other applications. This analysis investigates the effects of diesel oil contamination on the compaction properties of soil. The impact of diesel contamination on soil properties, particularly dry unit weight, is an important focus within geotechnical studies. The introduction of diesel into soil results in a decrease in dry unit weight. This reduction occurs because diesel occupies the void spaces between soil particles, hindering their dense packing arrangement and consequently lowering the overall density of the soil. Excessive diesel contamination diminishes inter-particle cohesion and increases the void ratio, leading to a less stable soil structure. The hydrophobic nature of diesel forms a coating around soil particles, which further reduces their ability to compact tightly and retain water. This phenomenon has been documented in studies by Ololade et al. (2019) and Akinwumi et al. (2014), which report a decline in dry unit weight at elevated levels of diesel contamination due to increased particle separation and diminished cohesion. In contaminated soil, the optimum moisture content gradually increases as the level of contamination rises in the soil samples. There is a marked increase in moisture content with higher diesel concentrations in the contaminated soil. This rise in optimum moisture content is associated with the effects of diesel oil on soil structure, necessitating more water to achieve optimal compaction due to reduced particle cohesion and elevated void ratios. Additionally, the reduction in cohesion contributes to an increase in void ratio.

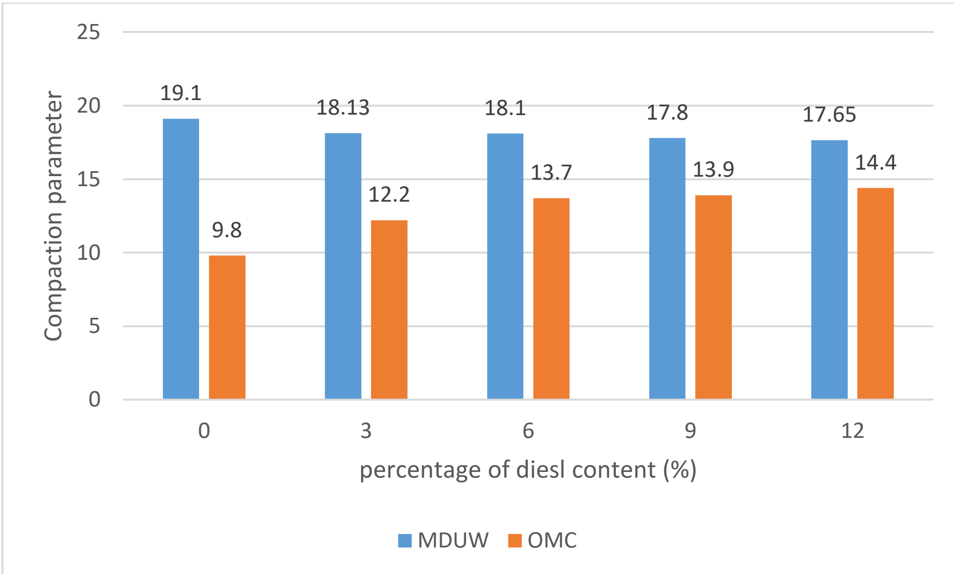


Figure 2: Compaction result of diesel contaminated soil

California Bearing Ratio (CBR)

The California Bearing Ratio (CBR) is a critical parameter in geotechnical engineering, particularly for assessing the strength and load-bearing capacity of soil. Diesel contamination introduces hydrocarbons into the soil matrix, resulting in alterations to particle interactions and cohesion among soil particles. The enhanced inter-particle slippage, attributed to the lubricating effects of diesel, diminishes shear strength and contributes to reduced load-bearing capacities. Research indicates that oil contamination can elevate liquid limits and plasticity indices, signifying a more plastic and less stable soil structure. Additionally, the presence of diesel may increase optimum moisture content while decreasing maximum dry density, further undermining soil stability. From the laboratory test results as shown in figure 4.6; The CBR value significantly declines as the concentration of diesel contaminant rises, thereby compromising the structural integrity of the soil.

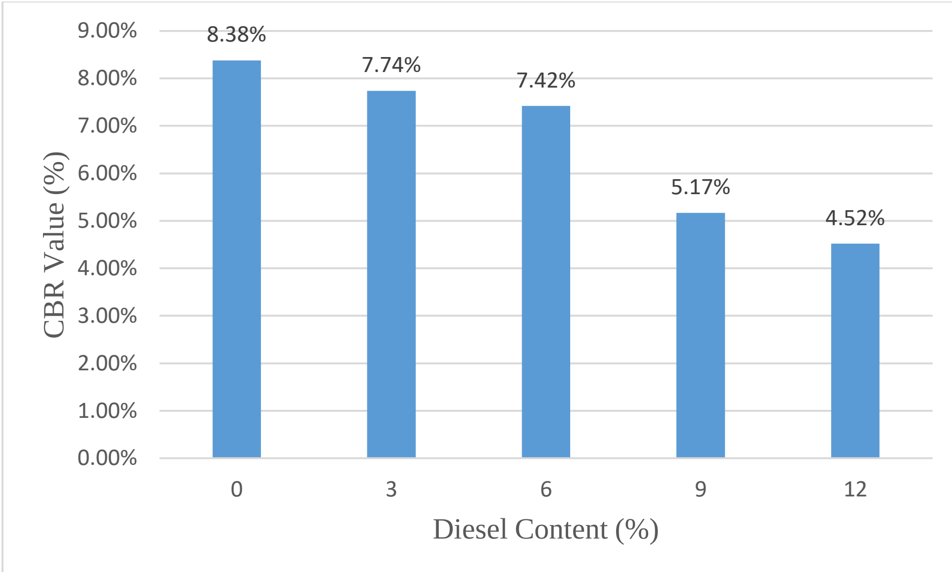


Figure3: Effect of diesel contaminant on CBR value

Unconfined Compressive Strength (UCS)

The laboratory results of Unconfined Compressive Strength (UCS) tests conducted on diesel-contaminated lateritic soil reveal a distinct trend of diminishing strength as the level of diesel contamination increases. The UCS values measured for various percentages of diesel (0%, 3%, 6%, 9%, and 12%) demonstrate a consistent decline, with an overall reduction of approximately 43% from 184 kN/m^2 at 0% diesel to 105 kN/m^2 at 12% diesel. This trend underscores the adverse effects of diesel on the mechanical properties of lateritic soil. The percentage reductions in UCS between successive diesel concentrations are particularly notable, especially between 9% and 12%, where a significant drop of 20% occurs, indicating that elevated levels of contamination severely undermine soil strength. The UCS values suggest that the contaminated soil may not be suitable for construction purposes without appropriate remediation measures.

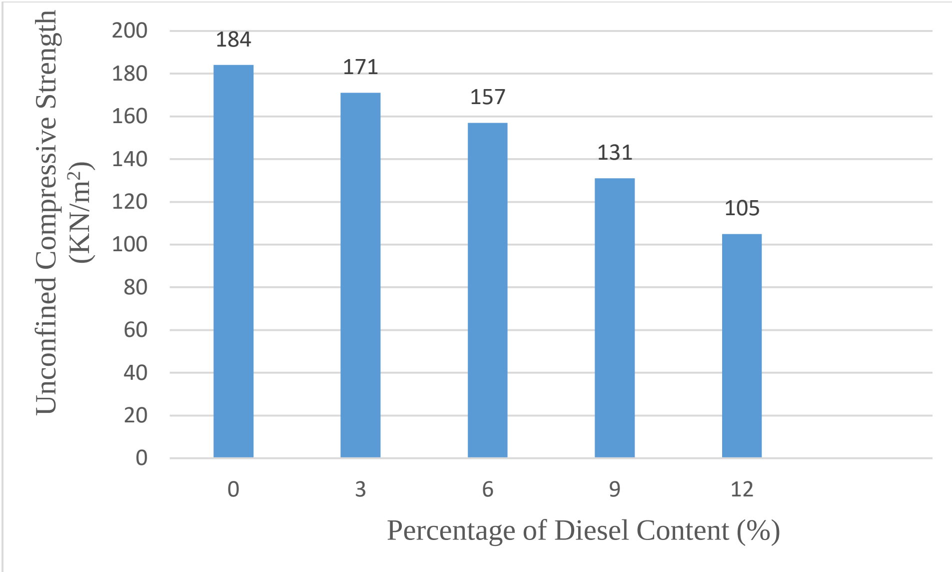


Figure 4: Effect of diesel contaminant on unconfined compressive strength

Effect of Lime Stabilization in Treatment of Diesel-Contaminated Soils

In this study, lime contents of 3%, 6%, and 9% were added to soil contaminated with 12% diesel to enhance its geotechnical properties. For comparative analysis, natural soil was also stabilized using 3%, 6%, and 9% lime. This serves as a control to assess the extent to which the geotechnical properties of the soil can be restored.

Atterberg limit

The effects of lime treatment on the liquid limit, plastic limit, and plasticity of soil contaminated with 12% diesel. The addition of lime results in a reduction of the liquid limit for 12% diesel-contaminated soils. Notably, the plastic limit of the soil tends to increase as the lime content rises. As regard the plastic index, the addition of lime reduce the plastic index of contaminated soil. Plastic

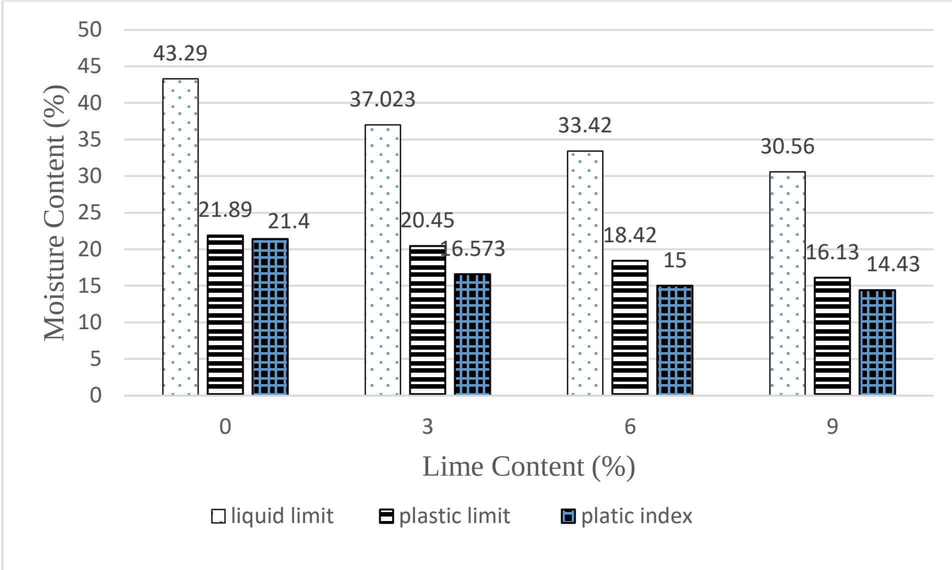


Figure 5: Effect of lime treatment on the Atterberg limit

Compaction

The effect of lime stabilization on the compaction parameters of 12% diesel-contaminated lateritic soil reveals significant findings. Diesel contamination typically hampers soil compaction efficiency due to its lubricating properties, which reduce friction among soil particles. However, the introduction of lime appears to mitigate these adverse effects by enhancing the soil structure and increasing the Maximum Dry Density (MDD).

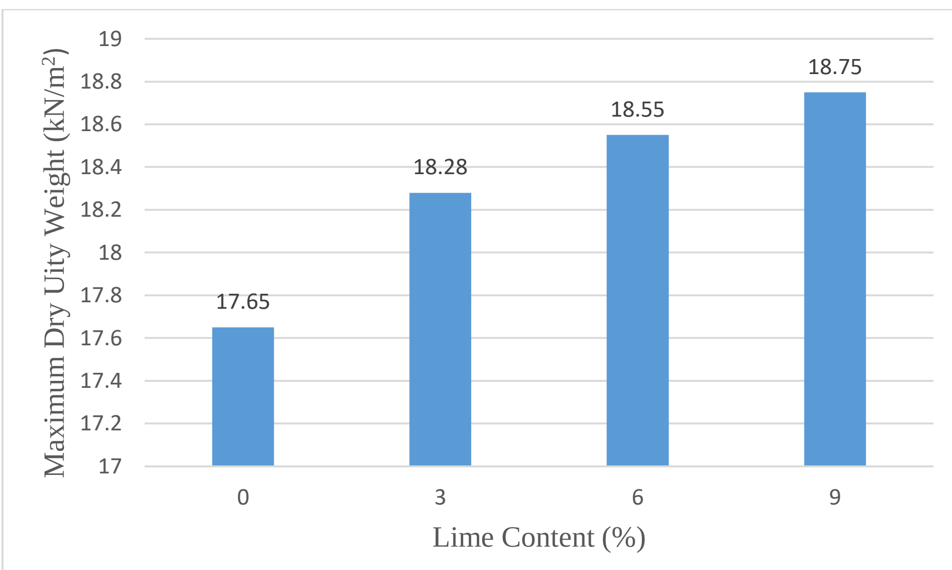
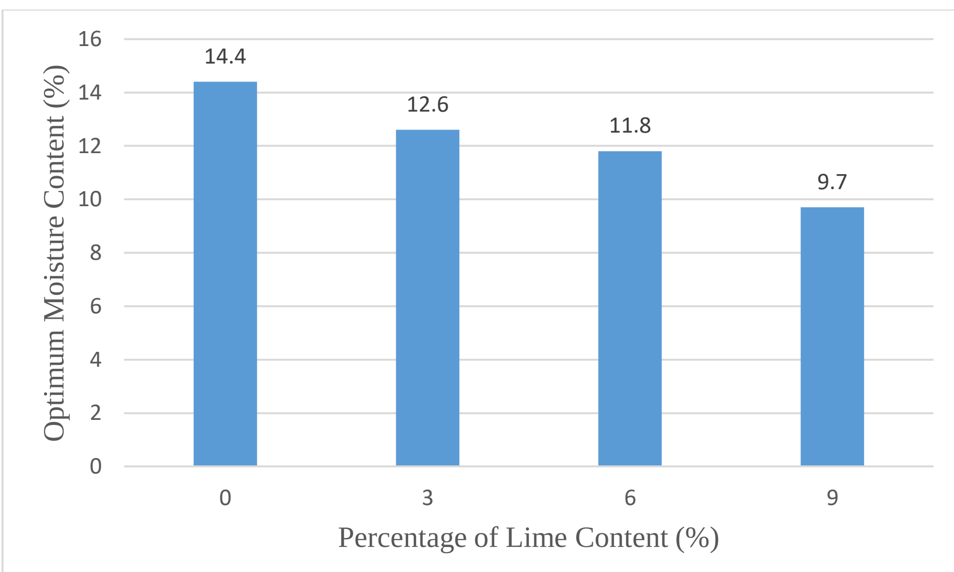


Figure 6: Effect of lime treatment on the maximum dry unit weight

The increase in MDD observed with lime treatment indicates that lime stabilization effectively counteracts the detrimental impacts of diesel contamination on soil compaction. This enhancement in density signifies an improvement in the soil's ability to achieve optimal compaction, which is crucial for engineering applications where structural integrity is paramount.

The treatment of diesel-contaminated lateritic soil with lime results in a marked improvement in maximum dry unit weight. This improvement underscores the efficacy of lime as a stabilizing agent, suggesting that it is a viable method for enhancing the compaction characteristics of lateritic soils affected by hydrocarbon contamination. The chemical interactions between lime and the soil constituents likely lead to changes in mineralogy and particle arrangement, contributing to a more stable and compactable material.

Research corroborates these findings; for instance, Correia et al. (2020) documented that lime stabilization significantly improved the mechanical properties of diesel-contaminated soils, reinforcing the observed trends in increased MDD with lime application. This body of work highlights lime's role not only in restoring but also in enhancing the geotechnical properties of contaminated soils, making it an effective strategy for remediation and reuse in civil engineering projects.

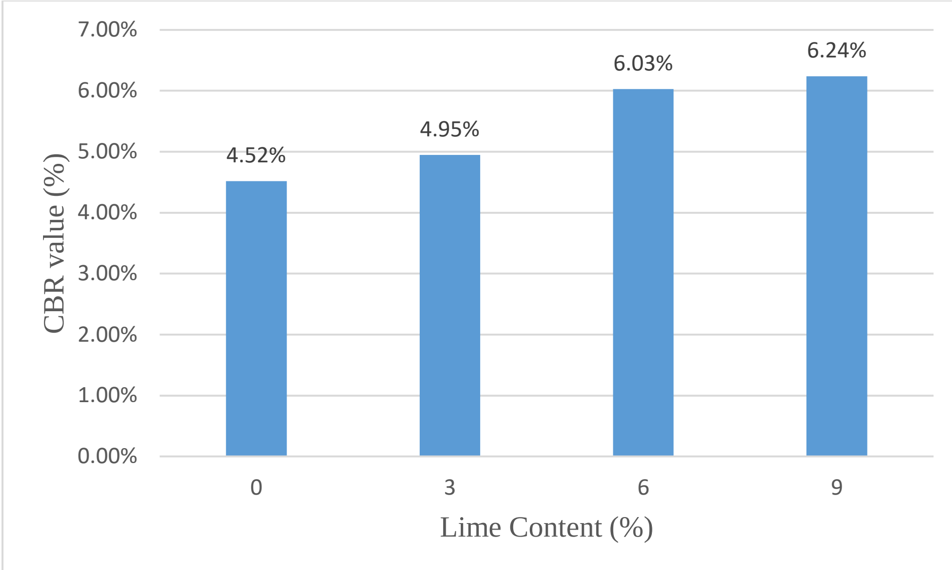


Effect of lime treatment on optimum moisture content of 12% diesel contaminated soil

The results demonstrate a consistent reduction in optimum moisture content (OMC) as lime content increases. This trend indicates that the incorporation of lime substantially enhances the soil's moisture retention capacity. The observed improvements are likely due to modifications in the soil structure and a decrease in plasticity. The addition of lime facilitates the flocculation of soil particles, resulting in a more cohesive and stable soil matrix. This stability allows for optimal compaction at lower moisture levels. Furthermore, the presence of lime alters the soil's mineralogical composition, leading to enhanced geotechnical properties. The chemical reactions between lime and soil constituents improve both the strength and stability of the material, effectively reducing the moisture content required for compaction. Supporting this analysis, Correia et al. (2020) found that lime stabilization significantly enhanced the mechanical properties of diesel-contaminated soils, corroborating the observed trends in moisture content reduction as lime levels increased. This evidence reinforces the effectiveness of lime treatment as a viable method for improving contaminated soil characteristics in engineering applications.

California Bearing Ratio (CBR)

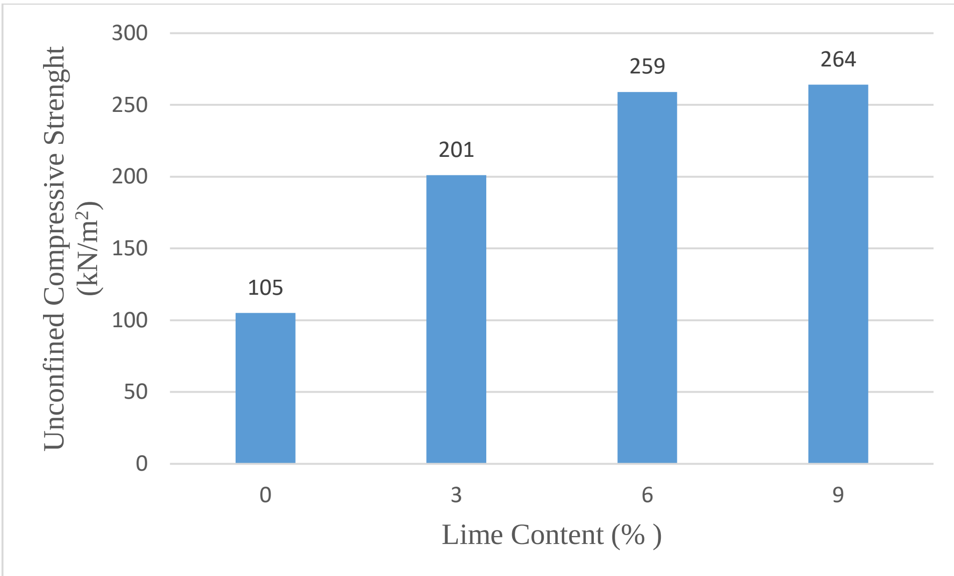
There is consistent increase in CBR values with the addition of lime. This trend suggests that lime treatment significantly enhances the load-bearing capacity of diesel-contaminated soil. The improvement in CBR values can be attributed to the chemical reactions between lime and the soil particles, which lead to the formation of cementitious compounds. These compounds enhance soil cohesion and stability, thereby increasing its strength and resistance to deformation under load**.**



Effect of lime treatment on CBR value of 12% diesel contaminated soil

Unconfined compressive strength (UCS)

The results of the Unconfined Compressive Strength (UCS) test conducted on a 12% diesel-contaminated lateritic soil treated with varying percentages of lime (3%, 6%, and 9%) offer valuable insights into the efficacy of lime as a stabilizing agent. The untreated soil displayed a UCS value of 105 kN/m^2, whereas the UCS values for the treated soils after 7 days of curing were as follows: 3% Lime: 201 kN/m^2, 6% Lime: 259 kN/m^2, and 9% Lime: 264 kN/m^2. These findings indicate a significant enhancement in UCS with increasing lime content. The UCS value of 105 kN/m^2 for the untreated soil highlights the adverse effects of diesel contamination on soil strength. The considerable increases in UCS for the treated soils underscore the beneficial impact of lime stabilization: an approximate increase of 91.4% was observed with 3% lime, while 6% lime resulted in an increase of about 146.7%. With 9% lime, the UCS further improved, yielding an increase of approximately 151.4%. This trend suggests that higher lime content contributes to enhanced soil cohesion and overall strength, likely due to chemical reactions that produce cementitious compounds and improve soil structure. Lime interacts with silica and alumina present in the soil, resulting in the formation of calcium silicate hydrates that bolster strength. Additionally, lime treatment facilitates flocculation and enhances compaction, thereby reducing voids and increasing density. According to ASTM D2166M, which outlines procedures for conducting UCS tests, the UCS values observed for treated soils significantly surpass typical minimum requirements for construction materials. For instance, many geotechnical applications necessitate UCS values exceeding 200 kN/m^2, indicating that both 6% and 9% lime treatments effectively meet these standards



Effect of lime in treatment on unconfined compressive strength of 12% diesel contaminated

Conclusion

A comprehensive experimental program was carried out to evaluate the impact of lime treatment on the geotechnical properties of coarse-grained soil contaminated with diesel. This program included an assessment of various soil characteristics, such as the plasticity index, compaction parameters, pH levels, and mechanical properties like CBR and UCS. The following conclusions can be drawn:

1. The evaluation of the chemical composition of lateritic soil revealed that its electrical conductivity was 924 µS/cm, organic carbon content was 1.19%, organic matter was

2.05%, exchange acidity measured 6.0 Meq/100g, and exchange bases were recorded at 14.10 Meq/100g. The soil pH was determined to be 11.20, and the cation exchange capacity was 20.10. In contrast, the diesel examined exhibited a density of 0.853 g/cm³, a specific gravity of 0.712, viscosity of 119.70 cP, and a flash point of 122°C. Additionally, the concentrations of phosphorus, calcium, and iron in the diesel were 3.93 mg/L, 7.55 mg/L, and 1.22 mg/L, respectively. Given the chemical composition of both the laterite and the diesel, it can be concluded that the diesel is likely to have detrimental effects on the geotechnical properties of lateritic soil upon contamination.

2. The index properties of the soil were assessed, revealing that the specific gravity, liquid limit, plastic limit, and plasticity index of the natural uncontaminated lateritic soil were 2.55, 31.3%, 18.86%, and 12.44%, respectively. This laterite demonstrated medium plasticity. Based on the AASHTO Soil Classification System, it was classified as A-2-6(0), while the Unified Soil Classification System identified it as SM (silty sand)
3. The presence of diesel affected consistency limits of natural soil, and the compaction parameter. Soil Compaction curves with diesel addition was significantly altered when compared to natural soil, decreasing maximum dry unit weight and increasing optimum moisture contents. Also the CBR value was altered showing a significant decrease in the CBR value as the diesel content increases. The unconfined compressive strength decrease significantly with the addition of diesel.
4. Lime treatment in diesel-contaminated soil results in a reduction of consistency limits. The compaction parameters of diesel-contaminated soils were modified by the presence of lime, leading to an increase in maximum dry unit weight and a decrease in optimum moisture content. Additionally, a notable improvement in California Bearing Ratio

(CBR) values was recorded as the contaminated soil treated with lime as well as the unconfined compressive strength.

Geotechnical properties assessed in this research indicate a potential reuse of diesel contaminated soil geotechnical applications after lime treatment. Results obtained in this study cannot be directly extrapolated to others soils and hydrocarbon contaminant.

Further research should be carried out to determine the optimum dosage of lime for required for full restoration of soil mechanical property.

References

Akinwumi, I.I., Diwa, D. and Obianigwe, N., 2014. Effects of crude oil contamination on the index properties, strength and permeability of lateritic clay. International Journal of Applied Sciences and Engineering Research, 3(4), pp.816-824.

Al-Sanad, H. A., Eid, W. K. & Ismael, N. F. 1995. Geotechnical properties of oil contaminated Kuwaiti sand. Journal of Geotechnical Engineering, 121, 407- 412

Chang, S.H. and Slattery, J.C., 1990. Nonlinear stability analysis of miscible displacements. Transport in Porous Media, 5(1), pp.49-69.

Ijimdiya, T. S. 2012. Effect Of Oil Contamination On Particle Size Distribution And Plasticity Characteristics Of Lateritic Soil. Advanced Materials Research, 367, 19- 25.

Iloeje, A. F., & Aniago, V. (2016). Effect of crude oil on permeability properties of the soil. International Journal of Trend in Scientific Research and Development, 1(1), 39-43.

Kermani, M. and Ebadi, T., 2012. The effect of oil contamination on the geotechnical properties of finegrained soils. Soil and Sediment Contamination: An International Journal, 21(5), pp.655-671.

Khamehchiyan, M., A. M. Charkhabi, and M. Tajik. 2007. Effects of crude oil contamination on geotechnical properties of clayey and sandy soils. Journal of Engineering Geology 89 (3–4):220–29.

Khosravi, E., Ghasemzadeh, H., Sabour, M. R. & Yazdani, H. 2013. Geotechnical Properties Of Gas Oil Contaminated Kaolinite. Engineering Geology, 166, 11-16

Nazir, A. K. (2011). Effect of motor oil contamination on geotechnical properties of over consolidated clay. Alexandria Engineering Journal, 50(4), 331-35.

Ostovar, M., Ghiassi, R., Mehdizadeh, M. J., & Shariatmadari, N. (2020). Effects of crude oil on geotechnical specification of sandy soils. Soil and Sediment Contamination: An International Journal, 30(1), 58-73.

Rahman, Z., Umar, H. & Ahmad, N. 2011. Engineering Geological Properties of Oil-Contaminated Granitic and Metasedimentary Soils. Sains Malaysiana, 40, 293-300

Rehman, H., Abduljauwad, S. N. & Akram, T. 2007. Geotechnical behavior of oil-contaminated fine-grained soils. Electronic Journal of Geotechnical Engineering, 12, 1-12.

Safehian, H., A. M. Rajabi, and H. Ghasemzadeh. 2018. Effect of diesel-contamination on geotechnical behavior of illite soil. Journal of Engineering Geology 241:55–63.

Shah, S. J., Shroff, A. V., Patel, J. V., Tiwari, K. C., & Ramakrishnan, D. (2003). Stabilization of fuel oil contaminated soil—A case study. Geotechnical & Geological Engineering, 21(4), 415-427.