# Impact of Oil Spills on Soil Strength Properties In Ogoniland, Niger Delta, Rivers State, Nigeria

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## ABSTRACT

The study is about the impact assessment of oil spill on soil strength properties of soil in Ogoniland. The aims are to determine the extent of the impact of the oil spills on the soil. The laboratory tests were limited to gradation, Atterberg limit tests, bearing capacity, settlement analysis, cohension and triaxial shear strength. Simplified Terzaghi-Meyerhof's and Terzaghi-Peck's equations were employed for the bearing capacity. Analyses showed that the site recorded increases in values of both ultimate capacity (qf) and safe bearing capacity (qs) with depth to oil spill; qs 90 kN/m2 at depth of 0.5 m to 174 kN/m2 at depth of 3.0 m. The calculated values of qs (90 – 174 kN/m$^2$) did not fall within established range of presumed bearing values for medium dense sand, which is 100 – 600 kN/m$^2$, thus, indicating that the soil have been altered seriously by oil spills and did not have good stability and cohension. The study recommended that quantitative data on oil spills and their effect on the soil and environment should be studied and made available to government, groups, or individuals who are involved in structure designing, civil engineering and construction works.


**Keywords:** Oil Spill Impact, soil stability, bearing capacity, Environment, Soil

## INTRODUCTION

Covering around 1,000 $km^2$ in Rivers State, Southern Nigeria, Ogoniland has been the site of oil industry operations since the late 1950s. Ogoniland has a tragic history of pollution from oil spills and oil well fires.

A chronic oil spill problems have been plaguing the Local Government Area of Ogoniland which comprises Eleme, Tai, Gokane and Khane Local Government councils for the past 30 years. Ecological, economic and environmental devastation which results from oil pollution through oil spillage remain unabated in the studied Area. The spills occasioned the weeding off of most crops and economic trees and killed almost all the fishes in the streams and ponds. It was very obvious that the survivors of several terrestrial organisms lost their natural food chain in their various ecological systems.

Due to oil spills the soil has lost its retentive capacities, therefore, erosion abounds, ponds and streams which were very friendly and productive had without notice turned to be their very enemies, making life more discomforting and unbearable.

The study therefore tends to study and investigate fully the negative effects of oil spills on the soil strengths properties of soil in communities of Ogoni in the Niger Delta Region of Nigeria.

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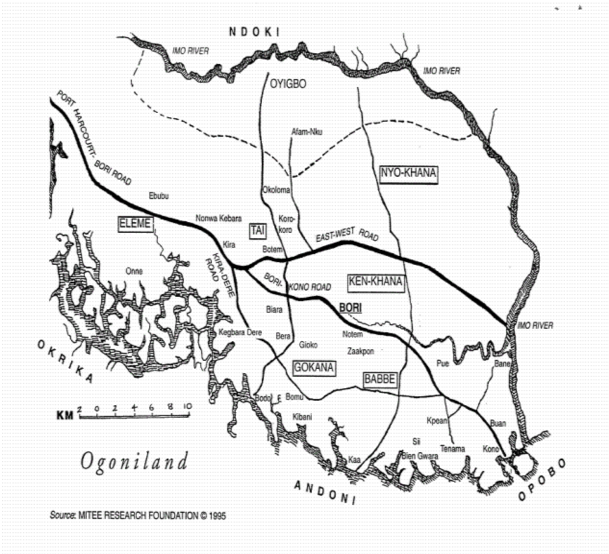


Fig. 1: Map of Ogoniland showing the four Local Government Areas

# METHODOLOGY

## Soil sampling

The sampling points were selected using grid method. A 6 inches diameter hand auger was deployed for the sample collection for all other tests excepting the triaxial shear strength. 2 in diameter tubes were utilized for the collection of soil samples for the triaxial shear strength tests. The necessary laboratory precautions were employed to prevent moisture alterations of the samples.

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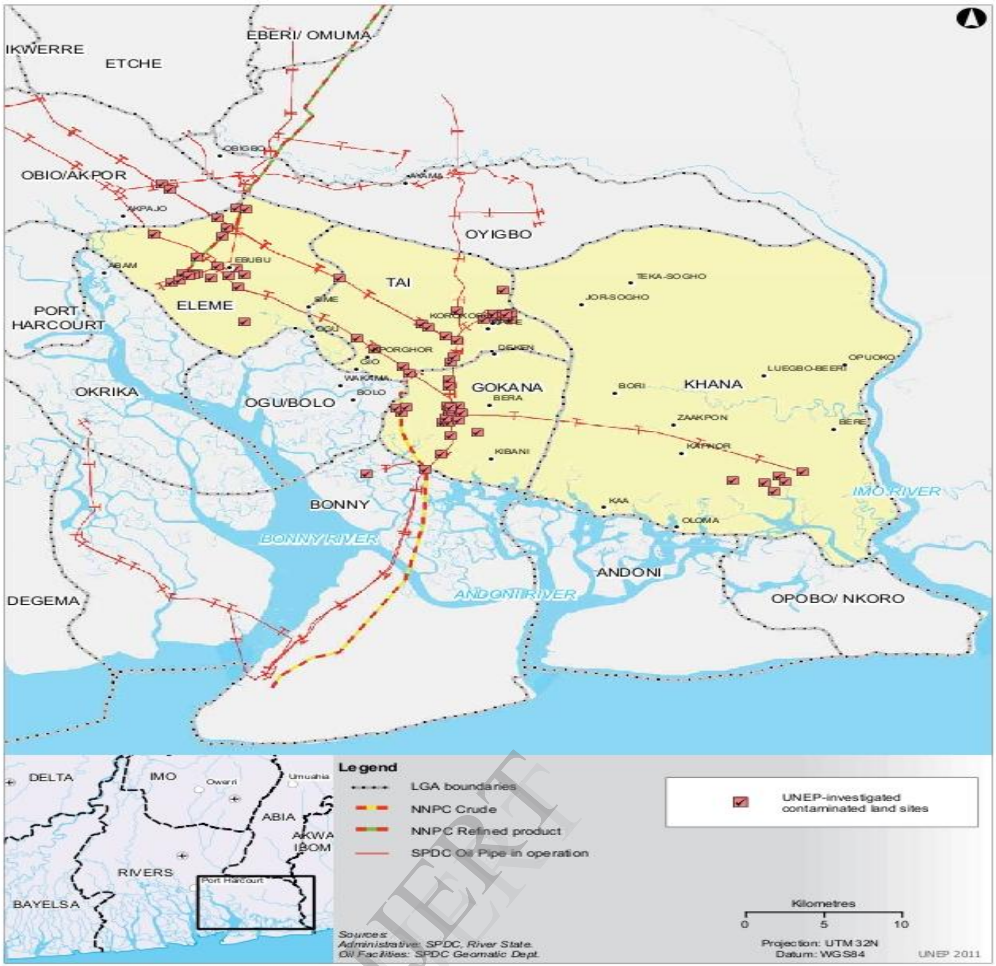




Fig: 2 Map of the study areas showing soil sample locations,,adapted from UNEP studies at Ogoni.

## Field Tests

Based on the data collected, field tests were conducted which include; indurations test, sheer strength text and relative density test.

Sheer strength, defined in terms of unconfined compressive strength, was estimated from the pressure required to squeeze an undisturbed oil spilled soil sample between fingers as described in table 2 and 3. Relative density which is important for cohesion less oil impacted soils was estimated from the ease at which a reinforcing rod penetrated the soil

Table 1: Describing Rock Induration
(Adapted from Duncan, 1967)

| Description | Unconfined Compressive Strength | Field Test |
|---|---|---|
| Very hard | 20,0001b/ (1400kg/cm$^2$) or more | Difficult to break 10-cm piece with pick |
| Hard | 8-20,0001b/(560-1400 kg/cm$^2$) | 10-cm piece broken with one hammer blow |
| Soft | 2.5-8000 1b/ (175-560 kg/cm$^2$) | Can be scraped, or dented slightly, with pick point |
| Very soft | 1-2500 1b/ (70-175 kg/cm$^2$) | Crumbles with pick, easily scraped with knife |



Table 2 Unconfined Compressive Soil Strength
(After terzaghi and peak, 1967)

| Unconfined Compressive Strength (After Terzaghi and Peak)[2:15] | | | |
|---|---|---|---|
| Term | Kips/ft$^2$ | KN/m$^2$ | Field Test (After Cooling, Skempton, and Glossop) [2:16] |
| Very soft | 0-05 | 0-25 | Squeezes between fingers when fist is closed |
| Soft | 0.5-1 | 25-50 | Easily molded pressure of fingers |
| Firm | 1-2 | 50-100 | Molded by strong pressure of fingers |
| Stiff | 2-3 | 100-150 | Dented by slightly by finger pressure |
| Very stiff | 3-4 | 150-200 | Dented only slightly by finger pressure |
| Hard | 44 | 200+ | Dented only slightly by pencil point |

Table 3: Soil Relative Density
(After terzaghi and peak, 1967)

| Term | Relative Density (%) | Field Test |
|---|---|---|
| Loose | 0-05 | Easily penetrated with 12-mm or ½-in reinforcing rod pushed by hand |
| Firm | 50-70 | Easily penetrated with 12-mm or ½-in reinforcing rod driven with 2.3-kg or 5-1b hammer |
| Dense | 70-90 | Penetrated a foot with 12-mm or ½-in reinforcing rod driven with 2.3-kg or 5-1b hammer. |
| Very dense | 90-100 | Penetrated only a few inches with 12-mm or ½-in reinforcing rod driven with a 2.3-kg or 5-1b hammer |
| Very stiff | 3-4 | 150-200<br>Dented only slightly by finger pressure |
| Hard | 44 | 200+<br>Dented only slightly by pencil point |



## IMPACT OF OIL SPILLS ON SOIL STRENGTH PROPERTIES OF OGONILAND

### Bearing capacity analysis for soil impacted with oil

Bearing capacity equation (Bc) utilized in the study is that given by Tezerghi and Meyerh, as follows;

$$qf = cNc + qoNq + \frac{1}{2} B\gamma N\gamma \qquad (1)$$

Where; qf is ultimate bearing capacity

qo is surcharge (i.e., weight of oil impacted soil above the foundation level).

$\gamma$ is unit weight of oil impacted soil

c is cohesion

B is width of foundation in oil spill area.

Nc, Nq and N$\gamma$ are bearing capacity factors and they depend on cohesion (c) and angle of internal friction (Ø).

Surcharge (qo) and unit weight of oil impacted soil ($\gamma$) are given below as equations (2)and (3), respectively:

$$qo = \gamma D \qquad (2)$$

$$\gamma = \rho g \quad (3)$$

Where; D is depth of foundation in oil impacted area.

ρ is specific gravity

g is acceleration due to gravity (approx. $10m/s^2$)

Safe bearing capacity was estimated using the expression below, according to Sowers and Sowers

$$qs = qf/SFM \quad (4)$$

Where, qs is safe bearing capacity

SFM is safe minimum permissible safety factor.

**Deductions and assumptions**

The values of c, Ø and γ were deduced from laboratory test result, the minimum values of the laboratory derived parameters (25 $kN/m^2$, 15° and 2.61 for c, Ø and γ, respectively) were used for the computation of the bearing capacity values of the oil impacted soil in the studied area.

Values of the bearing capacity factors (i.e., Nc, Nq and Nγ) were deduced from bearing capacity factors chart (Meyerhof curve see figure 3) and are as follows; 11, 4 and 3.5 for Nc, Nq and Nγ, respectively. Width of the structural foundation (B) was assumed to be 1 m, while SFM was assumed to be 2.5. Sowers and Sowers note that SFM value of 2.5 is effective and reliable for most range of structural projects. The required factor of safety depends on the type of structure, the type of soil and other factors and typically range between 2.0 and 3.5.

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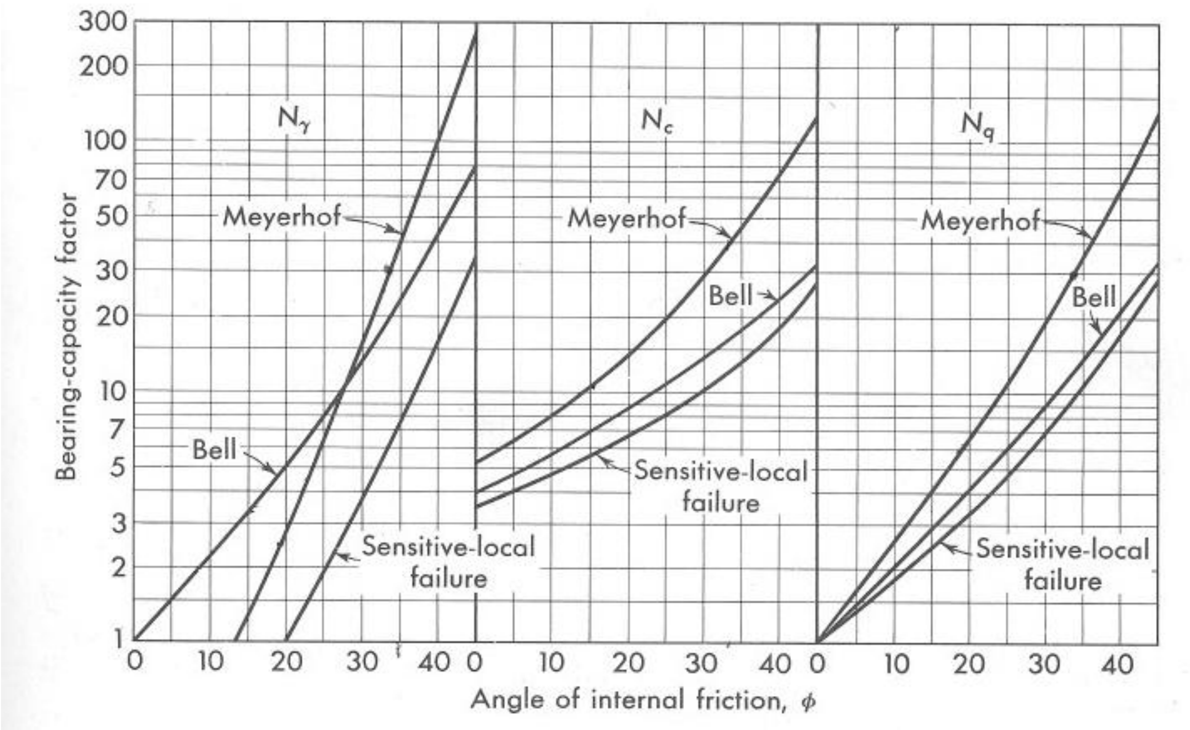


Figure 3: Bearing capacity factors for general bearing capacity equation.



**Settlement analysis**

Settlement was estimated using compressibility equation by Terzaghi and Peck, as given below;

**Cc = 0.009 (LL - 10)** **(5)**

Where**; Cc is compression index**

**LL is liquid limit**

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Table 4: Summary of bearing capacity analysis of the oil impacted soil

| **Depth (m)** | **qo (kN/m$^2$)** | **qf (kN/m$^2$)** | **qs (kN/m$^2$)** |
|---|---|---|---|
| 0.5 | 9 | 200 | 90 |
| 1.0 | 18 | 252 | 111 |
| 1.5 | 27 | 304 | 132 |
| 2.0 | 36 | 356 | 153 |
| 2.5 | 45 | 409 | 174 |
| 3.0 | 54 | 561 | 185 |

Table 5: Presumed bearing values of different types of soils

| Category | types of rocks and soils | presumed bearing value (Kn/m$^2$) |
|---|---|---|
| Non- cohesive soils | dense gravel or dense sand And gravel | >600 |
| | Medium dense gravel, or Medium dense sand and gravel | >200 to600 |
| | Loose gravel, or loose sand gravel | >200 |
| | Compact sand | >300 |
| | Medium dense sand | >100 to 300 |
| | Loose sand | >100[#] |
| Cohesive soils | very stiff bolder clays & hard clays | 300 to 600 |
| | Stiff clays | 150 to 300 |
| | Firm clay | 75 to 150 |
| | Soft clays and silts | >75 |
| | Very soft clay | Not applicable |
| | | Not applicable |
| Peat | | |
| Made ground | | Not applicable |



## Grain size distribution

The result of the gradation analyses of oil impacted soil samples are summarized in Table 9, while the average depth distribution of the particle-size is giving in Figure 4. Table indicates that the soil samples are sand dominated. Plots of the mean valve of the grain size in Figure 4 buttress the fact that soil sample were characterized by high percentage of sand (even with increase in depth), while the fines fraction slightly decreased with depth. No significant depth variation was shown in the percentage of gravel. Well graded sand is most often incompressible and reasonably permeable, thus, permitting easy penetration of oil spills which dissolves some materials from the soils.

Table 6: Range of grain size distribution of oil impacted soil sample

| Depth (m) | Fines (%) | parameter<br>Sand (%) | Gravel (%) |
|---|---|---|---|
| 1.0 | 28-36 | 60-68 | 2-4 |
| 2.0 | 22-23 | 62-74 | 4-8 |
| 3.0 | 22-24 | 71-74 | 2-5 |



## Result and discussion

***Atterberg limits and specific gravity***

The summary of the results of the Atterberg limits a carried out on the studied soil samples are presented in Tables 10. Results of gradation tests had shown that the amounts of fines are low,(table 9) Atterberg limits tests, however, gives indication that the fines have high values of liquid limits that even persisted with depth due to oil spill saturation .These high Atterberg limits reveal that the predominant sand is highly impacted with oil. A combination of the results of the gradation and Atterberg limits tests indicate that the soil is highly impacted with oil spills following Unified Soil Classification System.

Table 7: Range of Atterberg limits of oil impacted soil sample

| Parameter<br>Depth (m) | LL | PL | Pl |
|---|---|---|---|
| 1.0 | 60-66 | 35-39 | 24-30 |
| 2.0 | 55-63 | 33-37 | 21-26 |
| 3.0 | 53-58 | 32-35 | 19-24 |

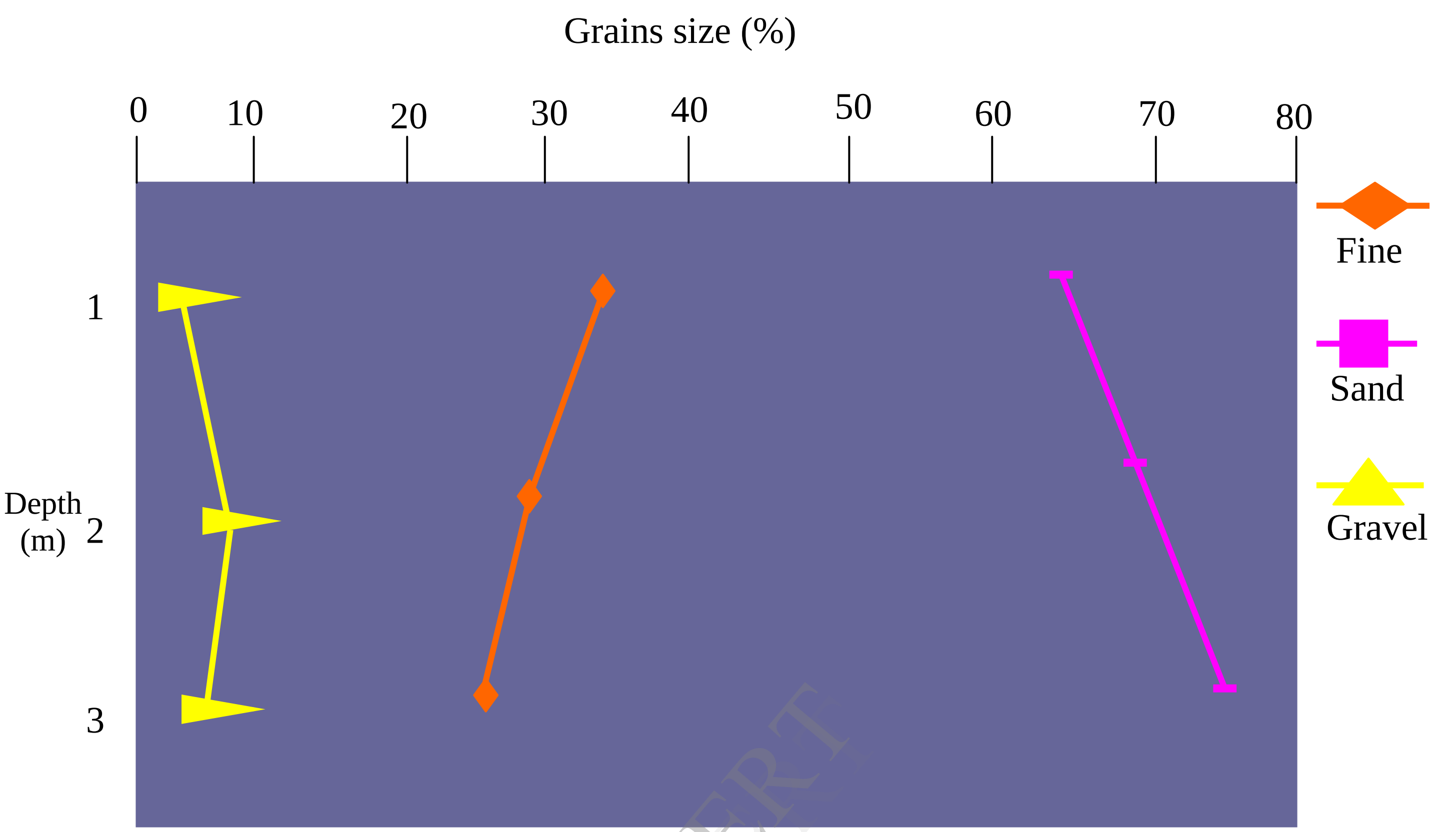


Fig. 4: Mean values of grain size distribution with depth



Table 8; Mean valve of specified gravity result and

Natural moisture content of oil impacted soil.

| Sample point* | specified gravity |
|---|---|
| Bara | 2.61 |
| Aleto | 2.62 |
| korokoro | 2.61 |
| Ebubu | 2.62 |
| Kpador | 2.61 |
| Bodo | 2.62 |

*sample depth 2m.

## Triaxial shear strength

The summary of the strength parameters [angle of shearing resistance (Ø) and cohesion (c) deduced from the laboratory triaxial shear strength tests are presented in Table 12 Results show that Ø and c have insignificant horizontal variation and are low in comparison with most stable soils ; generally below 250 and 35kN/m2, for Ø and c, respectively. These relatively low c and Ø values indicate that the soil may experience moderate to poor bearing capacity as this can lead to heaving and slumping

Table 9: Summary of the strength tests result of oil spill impacted soil.

| Sampling point strength parameters | (0) | c (KN/M$^2$) |
|---|---|---|
| Bara | 24 | 30 |
| Aleto | 15 | 35 |
| korokoro | 18 | 35 |
| Ebubu | 16 | 30 |
| kpador | 20 | 25 |
| Bodo | 15 | 50 |

## Sampling depth of 2m



## Summary

The soil strength investigation of oil impacted soils and empirical analysis carried out in this study have provided an insights into the effectiveness of the adopted procedure for oil impact assessment on soil. It was evident that the laboratory testes aided field observations and was useful in the determination of geotechnical properties of the oil impacted soil, following Unified Soil Classification System.

Bearing capacity analyses indicated that the estimated bearing capacity qs (90–185kN/m$^2$) falls well below the established range of presumed bearing values for medium dense sand (similar to the tested soil), which is 100 – 600 kN/m$^2$. Hence, to some degree of certainty, the study was able to establish bearing characteristics of the soil, buttressing the fact that the testing program and

analytical procedure were both effective and reliable for soil impacted oil assessment.

## Conclusion

Generally it has been deduced that Oil spill, and its associated pressure and uplift have the following effects on the soil strength in the studied area:

(a) It dissolves some materials from the soil

(b) It fills the pores and reduces the capillary tension that binds the grains together.

(c) It increases the bulk density of the material, so changing the stresses within the mass.

(d) Hydrostatic pressure exerts an all round tensile stress on the particles leading to "quick" condition.

(e) Oil flow, depending on direction, increases or decrease stability by reorienting the flow direction.

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