Effect of Oil Contamination on Engineering Properties of Surface Soil and Subsurface Water

Mayur S. Gaikwad[1], Sulochana D. Kambalwad[2], Mohmmed M. khan[3], Dr. S.G. Ban[4]
[1,2,3]*B. Tech Student, Department of Civil Engineering, G H Raisoni College of Engineering and Management, Wagholi, Pune-412207, Maharashtra, India*
[4]*Professor and Head, Department of Civil Engineering, G H Raisoni College of Engineering and Management, Wagholi, Pune-412207, Maharashtra, India*

Abstract— **Oil contamination caused by its spillage & leakage is serious concern for environment and civil engineering field. Following study highlights effect of oil contamination on engineering properties & nutrients of soil. Also its effect on subsurface water. Soil samples were formed with different percentage of used engine oil (0%, 5%, 10% & 15%) to simulate actual field conditions. Lab tests were done to find out changes in soil properties such as shear strength, compaction, permeability and plasticity. In addition to this, NPK analysis and basic water quality tests were also done.**
The result show that oil contaminations reduces soil strength, density and permeability, but increases plasticity. Nutrient analysis showed decrease in nitrogen and phosphorus content, with slight reduction in potassium. Changes were also seen in water's turbidity and dissolved oxygen content. A plant growth study confirmed that higher oil content causes reduced growth indicating poor soil condition. Our study highlights, oil contamination negatively affects both engineering properties and environmental quality. This emphasizes we need proper control and management of oil pollution to protect soil and water resources.

Keywords: ***Oil contamination, Black cotton soil, Engineering properties, NPK analysis, Water quality.***

I. INTRODUCTION

Soil plays a vital role in civil engineering. It supports structures like buildings, roads and bridges. The strength and stability of structures mainly depend on the properties of the soil on which its built. Because of this, understanding soil behaviour is essential for construction work. In today's time, soil contamination has become a growing concern due to increased number of industries and use of petroleum products. Oil contamination generally happens because of leakage of petrol, diesel, engine oil and other lubricants from vehicles, pipelines and workshops. When oil is mixed with soil, it changes its natural properties and reduces its strength and load bearing capacity. Black cotton soil is found in many parts of India. It is known for its swelling and shrinkage nature. It expands after absorbing water and shrinks after drying. This causes cracks in structures and damages the pavements. When this soil is contaminated with oil, its engineering properties are further degraded, and becomes less reliable for construction purposes.

In this study, black cotton soil samples are prepared with different levels of oil contamination (0%, 5%, 10% and 15%). Laboratory tests such as compaction, unconfined compressive strength and permeability are carried out to observe how these properties change with contamination. The main aim of this study is to understand the effect of oil contamination on the engineering behaviour of black cotton soil. The results will help in identifying the impact of contamination and highlight the need for proper control of oil leakage in construction area.
This below fig. I, shows the difference between polluted and clean environmental conditions. On the left side, oil contamination damages soil and water, making it harmful for plant growth. The soil becomes weak and the water becomes polluted, affecting the ecosystem. On the right side, clean soil and water support healthy plants and a balanced environment.

Fig. I: Environmental Impact of Oil Contamination

This below fig. II, shows the impact of oil contamination on soil, water and plant growth. Polluted soil and water reduce plant growth and damage the environment. Oil makes the soil week and blocks proper water movement. Clean conditions help plants growth better and maintain a healthy ecosystem.

Fig. II: Effect of Oil Contamination on Soil, Water and Plant Growth

1.1 Background of the Study

Now a days, soil contamination due to oil leakage is becoming a common problem in civil engineering. Oil from vehicles, pipelines and workshops can easily mix with soil and change its natural properties. This affects important factors like strength, compaction and permeability. The issue becomes more serious in black cotton soil, which already has swelling and shrinkage behaviour. When oil mixes with this soil, its performance reduces further and it becomes less suitable for construction work. It can also affect nearby subsurface water. Because of these reasons, it is important to study how oil contamination changes soil behaviour. This helps in understanding the problem and highlights the need to control oil pollution.

II. AIM AND OBJECTIVE

A. Aim

The main aim of this study is to check how oil contamination affects the engineering properties of black cotton soil and its impact on groundwater.

B. Objectives

a) To prepare soil samples with different percentages of oil contamination like 0%, 5%, 10%, and 15%.
b) To study the changes in engineering properties such as Atterberg limits, compaction, strength and permeability.
c) To check how increasing oil content changes the behavior of black cotton soil.
d) To check oil contamination affects ground water quality.

III. METHODOLOGY

The following steps are to be followed:

A. Literature & Problem Understanding
   a. Previous Studies research on oil contaminated soil and its effect on engineering properties such as strength, compaction and permeability.
   b. Study standard laboratory methods and guidelines related to soil testing and water quality analysis.

B. Soil Collection
   a. Black cotton soil was collected from a nearby open ground area after removing the top organic layer.
   b. Oil-contaminated soil samples were also collected from a nearby factory area where oil leakage was observed.
   c. Disturbed sampling method are used.

C. Laboratory Testing
   a. Conducted engineering tests such as Atterberg limits, compaction test, unconfined compressive strength and permeability test.
   b. Performed NPK testing to evaluate changes in soil nutrient content.

D. Water Quality Analysis
   a. Contaminated water samples wear prepared and carried out tests such as pH, turbidity and dissolved oxygen (DO).
   b. Analyased the effect of oil contamination on groundwater quality.

E. Plant Growth Study & Result Analysis
   a. Conducted plant growth experiments using normal and contaminated soil to observe growth variation.
   b. Compared all results and analyzed the effect of increasing oil contamination on soil properties, water quality and plant growth.

IV. RESULT AND DISCUSSION

A. Analysis of Engineering Properties of soil

The comparison between normal soil and oil-contaminated soil shows significant changes in engineering properties. The effect of oil contamination like 0%, 5%, 10% and 15% on engineering properties of soil.

Table I: The effect of oil contamination such as 0%, 5%, 10% and 15% on engineering properties of soil samples.

Oil content (%)	Shear strength (N/m^2)	MDD (g/cc)	OMC (%)	Permeability (cm/s)
0	25	1.75	16	2.5×10^{-5}
5	22	1.70	15	3.2×10^{-5}
10	18	1.65	14	4.5×10^{-5}
15	14	1.60	13	6.0×10^{-5}

Fig. III: Oil % vs Shear Strength

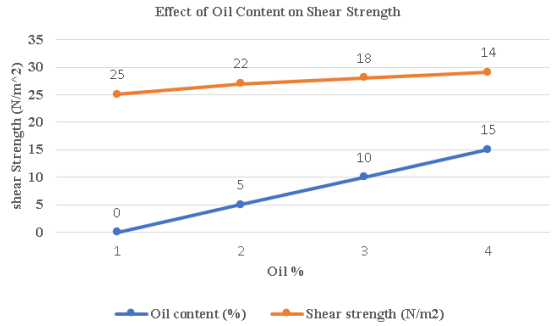


Fig. IV: Oil % vs MDD

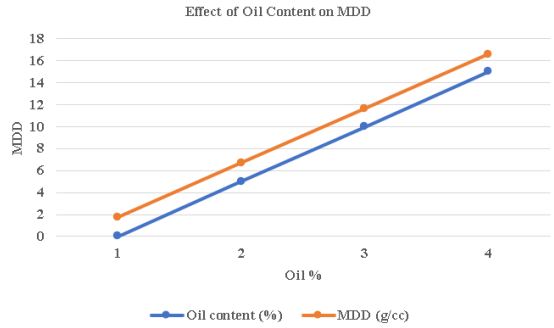
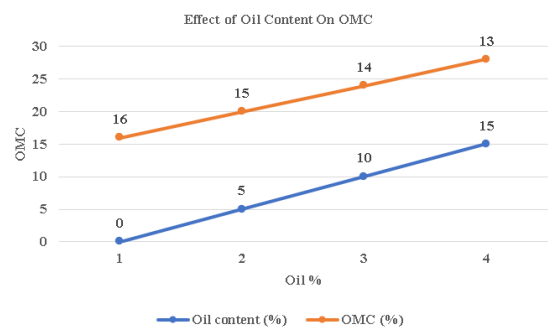


Fig. V: Oil % vs OMC



B. Analysis of Engineering Properties of Water

Water property analysis means checking the quality of water to understand whether it is suitable for construction and environmental use. Poor water quality can affect soil behavior, reduce concrete strength and overall safety of structures.

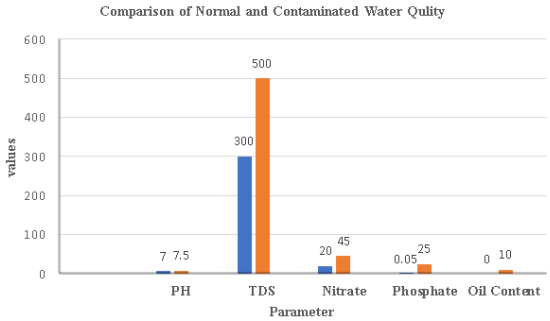
Table II: Comparison of Normal and Oil Contamination Condition of Water Quality.

Property	Normal Condition	Oil Contaminated Condition
Colour	Light	Dark
Texture	Granular	Sticky
NPK Value	Balance	Reduced
Water Quality	Good	Poor

Table III: Water testing (Normal vs Contaminated)

Parameter	Normal Water	Oil Contaminated Water	Remark
PH	7.0	7.5	Acceptable
TDS	300 mg/L	500 mg/L	Increased
Nitrate	20 mg/L	45 mg/L	At Limit
Phosphate	0.05 mg/L	25 mg/L	High
Oil Content	0 mg/L	10 mg/L	Contaminated

Fig. VI: Comparison of Water Quality Parameter



C. Analysis of NPK Values

NPK testing is performed to check the amount of nitrogen, phosphorus and potassium in soil and water. It helps to study soil fertility and the effect of contamination on nutrient quality.

Table III: NPK testing result

Parameters	Result (kg/ha)	Limit (kg/ha)	Remark
Nitrogen	286.0	281-420	Optimum
Potassium	185.0	151-200	Optimum
Phosphorous	19.5	14.01-21.0	Optimum

V. CONCLUSION

This project studied the effect of oil contamination on soil, water, nutrients NPK and plant growth. The results show that oil pollution has a negative effect on soil and water. In soil, it reduces strength, blocks

pores and decreases permeability and dry density, so the soil becomes unsuitable for construction. It also makes the soil sticky and more plastic in nature.

Oil contamination also reduces soil fertility by decreasing nutrients like (NPK) nitrogen, phosphorus and potassium. The oil also drains away important nutrients NPK, which stops plants from growing healthy roots or leaves. Water quality also gets affected, as oil increases turbidity, lowers dissolved oxygen and makes water unsafe. Plant growth is also reduced, with poor germination, weak roots and yellow leaves. Overall, oil contamination damages soil, water and plant health, so proper control and treatment are necessary.

REFERENCES

[1] P. K. Singh and A. Kumar, "Impact of hydrocarbon contamination on soil permeability and consolidation behavior," Environmental Geotechnics, vol. 12, no. 1, pp. 89–101, 2025.

[2] "Y. Zhang, H. Liu and X. Chen" (2025), Mechanical behavior of petroleum-contaminated soil and its stabilization using cement-based materials, Construction and Building Materials, vol. 430, 2025.

[3] "S. K. Sharma and R. K. Gupta" (2024), Experimental study on strength and compaction characteristics of oil-contaminated clay soil, International Journal of Geotechnical Engineering, vol. 18, no. 4, pp. 455–463, 2024.

[4] M. A. Akinwumi and O. O. Diwa, "Effect of used engine oil contamination on the geotechnical properties of lateritic soil," Journal of Materials in Civil Engineering, vol. 36, no. 2, 2024.

[5] C. Zhao, Y. Dong, Y. Feng, Y. Li and Y. Dong, "Thermal desorption for remediation of contaminated soil: A review," Chemosphere, vol. 221, pp. 841-855, 2019.

[6] S. George, E. Aswathy, B. Sabu, N. Krishnaprabha and M. George, "Study on geotechnical properties of diesel oil contaminated soil," International Journal of Civil and Structural Engineering Research, vol. 2, no. 2, pp. 113-117, 2015.

[7] C. Devatha, A. Vishnu Vishal and J. Purna Chandra Rao (2019), "Investigation of physical and chemical characteristics on soil due to crude oil contamination and its remediation," Applied Water Science, vol. 9, pp. 1-10, 2019.

[8] A. Salimnezhad, H. Soltani-Jigheh and A. A. Soorki, ``Effects of oil contamination and bioremediation on geotechnical properties of highly plastic clayey soil," Journal of Rock Mechanics and Geotechnical Engineering, vol. 13, no. 3, pp. 653-670, 2021.

[9] J. R. Oluremi, P. Yohanna and S. O. Akinola, "Effects of compactive efforts on geotechnical properties of spent engine oil contaminated laterite soil," Journal of Engineering Science and Technology, vol. 12, no. 3, pp. 596-607, 2017.

[10] J. R. Oluremi and O. M. Osuolale, "Oil contaminated soil as potential applicable material in civil engineering construction," Journal of Environment and Earth Science, vol. 4, no. 10, pp. 87-99, 2014.

[11] I. Obeta and O. Eze-Uzomaka, "Geotechnical properties of waste engine oil contaminated laterites," Nigerian Journal of Technology, vol. 32, no. 2, pp. 203-210, 2013.

[12] E. Khosravi, H. Ghasemzadeh, M. R. Sabour and H. Yazdani, "Geotechnical properties of gas oil-contaminated kaolinite," Engineering Geology, vol. 166, pp. 11-16, 2013.

[13] M. T. Alfach and S. Wilkinson, "Effect of crude-oil-contaminated soilon the geotechnical behaviour of piles foundation," Geotechnical Research, vol. 7, no. 2, pp. 76-89, 2020.

[14] S. A. Nasehi, A. Uromeihy, M. R. Nikudel and A. Morsali, "Influence of gas oil contamination on geotechnical properties of line and coarse grained soils," Geotechnical and Geological Engineering, vol. 34, pp. 333-345, 2016.

[15] A. M. Eissa, "Effects of gasoline-contamination on geotechnical properties of clayey soil," in African Young Geotechnical Engineers Conference (AYGEC'16), Ghana, vol. 12, 2016.

[16] M. Nazari Heris, S. Aghajani, M. Hajialilue-Bonab and H. Vafaei Molamahmood, "Effects of lead and gasoline contamination on geotechnical properties of clayey soils," Soil and Sediment Contamination: An International Journal, vol. 29, no. 3, pp. 340-354, 2020.

[17] R. Patel and D. Mehta, "Assessment of groundwater quality affected by oil contamination in urban areas," Journal of Environmental Engineering, vol. 152, no. 3, 2026.