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Impact of Crude Oil Pollution on some Geotechnical Characteristics of North Rumaila Soils in the Southern Iraqi Province of Basrah Governorate

Ahmed K. Al-Nimah[1, *] Raid A. Mahmood[2]

[1] Iraqi Drilling Company-State Company, **ahmedkadem81@yahoo.com**, Basrah, Iraq.

[2] Department of geology, College of Science, University of Basrah, raidaziz14@yahoo.com , Basrah, Iraq.

***Corresponding author email:** ahmedkadem81@yahoo.com ; mobile: 07722494367

تأثير التلوث بالنفط الخام على بعض الخصائص الجيوتكنيكية لترب شمال الرميلة في محافظة البصرة جنوب العراق

احمد كاظم النعمة*[1]، رائد عزيز محمود[2]

[1]شركة الحفر العراقية، ahmedkadem81@yahoo.com، البصرة، العراق ،

[2]كلية العلوم، جامعة البصرة، raidaziz14@yahoo.com، البصرة، العراق ،

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ABSTRACT

Background:

Pollution affects the soil and results in a change in its natural, chemical, or organic characteristics and properties, which directly or indirectly affect the geotechnical properties of the soil and make it unsuitable for engineering use. The aim of the study is to determine how adding various amounts of crude oil to the study area's soil affects the soil's geotechnical characteristics, including soil shear resistance, compaction coefficients, and California bearing capacity.

Materials and Methods:

The North Rumaila site was chosen for the study. At a depth of one meter, natural, pollution-free soil was extracted, and weight percentages of 2%, 4%, 6%, 8%, and 10% of crude oil were added. Grain size analysis, moisture content, direct shear, compaction, and Californian bearing tests were conducted.

Results:

The findings indicate that the soil at the North Rumaila site has a moisture content of 6.45% and is mostly silty sand with small amounts of clay and gravel. Crude oil was added to the soil, which caused the Californian to lose some of its bearing capacity, the optimal moisture content to raise, the angle of internal friction to decrease, and the bearing capacity of the soil to decrease.

Conclusion:

Pollution by crude oil effects negatively impacted the soil's geotechnical qualities.

Keywords: Oil pollution; Basrah soil; geotechnical properties; North Rumaila soil; volumetric analysis.

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INTRODUCTION

Pollution is defined as the process that makes land, water, or air unsafe for use. It affects the soil and results in a change in its natural, chemical, or organic characteristics and properties, which directly or indirectly affect the geotechnical properties of the soil and make it unsuitable for engineering use [1].

Because enormous amounts of petroleum products can enter the environment through a variety of channels, including damaged pipelines, tanker accidents, reservoir tanks, marine oil production, and natural oil spills, oil pollution poses a threat to the ecosystem [2]. The geotechnical characteristics of the soil are altered as a result of this pollution, seriously jeopardizing the structural integrity of the engineering facilities constructed on it. Moreover, oil contamination lowers the soil's carrying capacity and hinders its ability to support large engineering structures, which causes the foundations beneath the structure to settle [3].

Some studies examined the effects of oil pollutants on low-plastic clay soils (CL) and sandy silty soils (SM). It was noted that the specific gravity slightly decreases as the crude oil content increases in soil because it contains organic materials with a low specific gravity [4], while both of the plasticity and liquid limits increase as the oil content increases [5], whereas the Atterberg's limits values decrease with increasing the oil content [6].

In terms of the maximum dry density, when a soil is contaminated with oil, this leads to decrease its maximum dry density as a result of filling the soil gaps with oil, which causes decline in the density of soil [7]. on the contrary, increasing the percentage of oil produces a rise in the maximum dry density in highly plastic soils [3]. Keep in mind in sandy soil, the optimum water content drops down as the oil content rises up [5].

Regarding the effect of oil content in soil on the California bearing capacity (CBR), it was found that the CBR ratio of submerged and non-submerged soil samples increase with the increase the quantity of crude oil in soil [8]. On the other hand, when the oil concentration rises up, California's bearing capability drops down [9].

Also, when the oil content increases in soil, it leads to decrease both of the cohesion and ion exchange capacity of the soil [10] and drastically decrease the internal friction angle of sandy soil [11].

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Furthermore, it was experimentally approved that as the contamination of sand samples by crude oil increases, the values of maximum dry density, optimum water content, and the angle of internal friction of sands decline [12]. Likewise, it was found that up to 3% of different oil addition to dried clayey sand soil increased compressive strength and cohesion coefficient but reduced internal friction angle, while higher oil content reduced all geotechnical properties except cohesion coefficient. Thus, attention must be paid to contaminated soils with crude and used engine oils before conducting geotechnical designs [13].

A review on the impact of petroleum spills on geotechnical properties of soils in Nigeria was conducted by [14], who found that the crude oil reduces the Atterberg limits, compression index, and soil permeability, with effects varying based on oil volume and soil biochemical properties.

The goal of the study is to determine how adding various amounts of crude oil to the study area's soil affects the soil's geotechnical characteristics, including soil shear resistance, compaction coefficients, and California bearing capacity.

DESCRIPTION OF THE STUDY AREA

The North Rumaila oilfield site, which is situated at the junction of longitude (30°34'18.79"N) and latitude (47°19'53.43"E), was selected to investigate the impact of pollution, as depicted in Figure 1.

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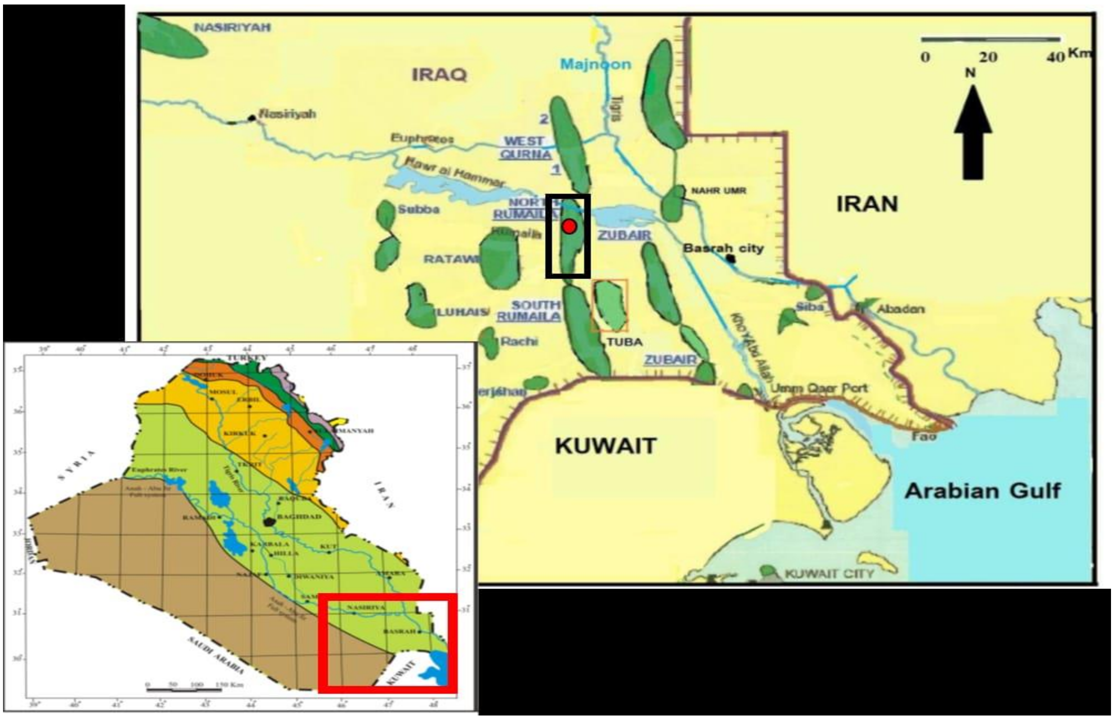

Figure 1: Location map of the current study area

MATERIALS AND METHODS

The North Rumaila field site, or the fourth station in the Al-Zubair district, was selected as the study's location in order to meet its objective. Using a hand auger, natural samples were collected from the first meter. They were sealed in plastic bags and then brought to the laboratory in order to perform geotechnical testing.

Laboratory tests:

Particle Size Distribution: The dry sieving method was used in the volumetric analysis of non-cohesive soils according to the American standard [15]. The test took place in the Basrah Construction Laboratory.

Moisture Content: The test was conducted in the laboratories of the Department of Earth Sciences/University of Basrah according to the American standard [16].

Direct Shear Test: The test aims to calculate shear coefficients in the soil. A sample of soil in its natural state extracted from the first meter at the North Rumaila site was prepared after it was passed through a No. 4 sieve (4.75 mm) according to the American standard [17], and a direct shear test was conducted on it. Following that, five soil samples were made and five different weight percentages of crude oil were added to them: 2, 4, 6, 8, and 10%. After homogenizing the mixture for a whole day, the samples were evaluated in the Basrah Construction Laboratory.

Compaction Test: By determining the maximum dry density (MDD) and the optimum moisture content (OMC), compaction tests on soil both on location and in the lab are performed to ascertain the highest degree of soil compaction that is achievable. These tests are of two types: the Standard Compaction Test, which is known as the Procter Test which was used in the study, and the Modified Compaction Test. A sample of soil in its natural state was prepared, extracted from the first meter of North Rumaila soil, and then four weight percentages of water were gradually added to it: 4, 8, 12, and 16% to determine the maximum dry density and the optimal water content. Subsequently, five samples were created by combining the appropriate amount of water with weight percentages of crude oil—2, 4, 6, 8, and 10%—in order to determine the optimum moisture content of the natural model. These samples were left for 24 hours for the mixture to homogenize to determine the percentage of optimal moisture content and maximum dry density with the addition of crude oil. Then, in accordance with the American standard [18], the standard Proctor tests were performed on them in the Basrah Construction Laboratory.

California Bearing Ratio (CBR): This test is used to evaluate the bearing capacity of the subsoil by inserting a cylindrical piston as a result of the loads placed on it and at a specific speed into the soil. A sample was prepared in its natural state extracted from the first meter of North Rumaila soil, and the optimum amount of water content determined from the compaction test was added to it. The sample was then immersed in water for 72 hours according to the American standard [19], to determine the California bearing ratio. After that, five samples of soil containing the optimum moisture content were prepared, and five weight percentages of crude oil were added to them: 2, 4, 6, 8, and 10%. Leave the mixture for 24 hours to homogenize, and then conduct a California bearing test on them.

The Zubair field provided the crude oil for the study, which was transported in and had its qualities determined beforehand. Viscosity, density, specific gravity, and the American Petroleum Institute (API) requirements are these qualities (Table 1). The crude oil was tested at the University of Basrah's College of Engineering's Petroleum Engineering Department.

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Table 1: Characteristics of the crude oil used in the study.

Density (at 40 °C) g/cm^3	**0.9126**
Specific gravity	**0.9142**
API	**25.5**
Viscosity at 40 °C	**91.84**

RESULTS AND DISCUSSION

The research results show the following:

Particle size distribution: As illustrated in Figure 2, the findings of the volumetric analysis of the soil sample from the North Rumaila site reveal that the percentages of gravel, sand, silt, and clay are 2%, 66%, 25%, and 7%, respectively. As a result, it is referred to as silty sand soil that contains some gravel and clay.

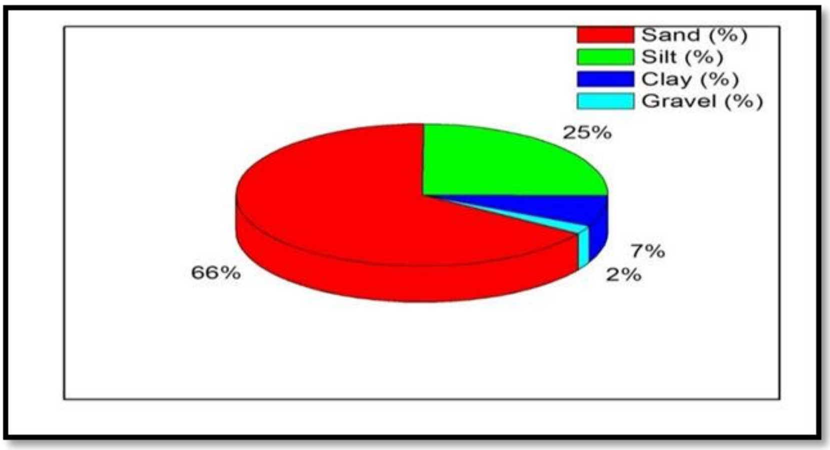

Figure 2: Particle size distribution of the soil sample at the North Rumaila oilfield site.

Moisture content: The findings indicate that the soil has 6.45% moisture content. This value is small, and this is due to the fact that sandy soils have high permeability, which leads to easy movement of water and a lack of retention. Also, as a result of the depth of the groundwater, which ranges from 5 to 7 m at the site, the continuous drying as a result of high sunlight, and the lack of capillary properties in the soil.

Direct shear test: The findings indicate that, as it has been shown in Figure 3, the sample's angle of internal friction (Ø) in its unaltered natural condition is 33°. However, when the crude oil substance was added to the soil samples in different

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amounts, a decrease in the angle's value was seen. For example, the angle's value dropped to 29º and 30º, respectively, after 8 and 10% of crude oil was added. The angle of internal friction in sandy soil decreased as a result of the shear resistance and friction being reduced by crude oil, which filled the pores in the soil, surrounded the grains, and made it easier to slide over one another.

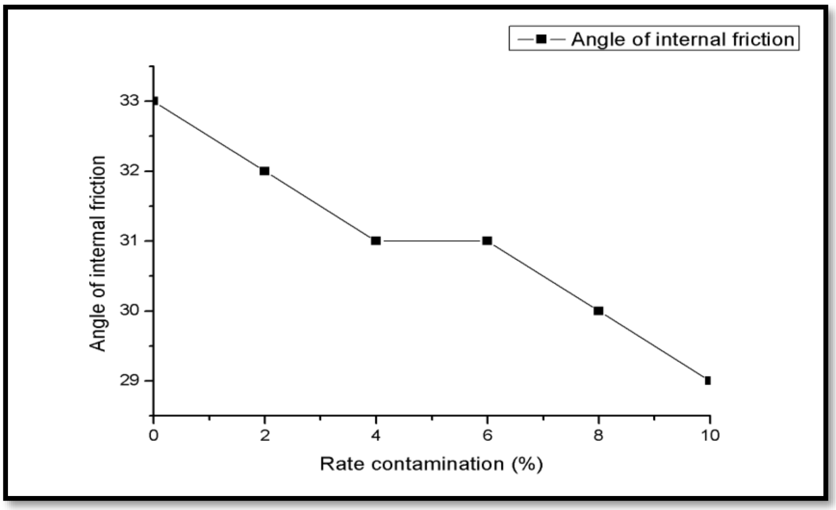

Figure 3: The difference between the soil sample's internal friction angle before and after adding crude oil to the research region.

Compaction test: A standard compaction test was conducted on a natural sandy soil sample in order to ascertain the values of the maximum dry density (MDD) and optimum water content (OMC). The results showed that the maximum dry density is 1.989 g/cm^3 and the optimum water content value is 13.5%, as shown in Figure 4.

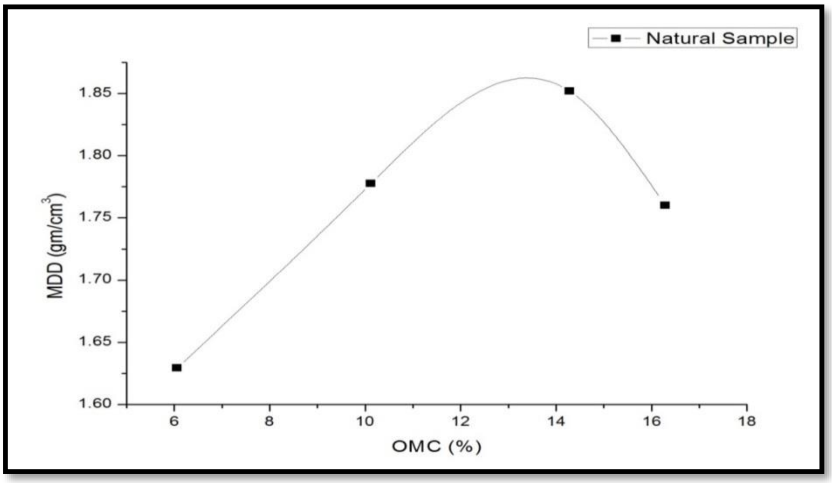

Figure 4: Maximum dry density and optimal moisture content for the natural sample.

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The optimum water content value (13.5%) was used to determine the dry density value when adding the crude oil material at rates of 2, 4, 6, 8, and 10% to determine the extent to which the dry density values are affected by the crude oil material. The results show a decrease in the maximum dry density value with an increase in the percentage of crude oil, as its value reached 1.704 g/cm^3 and 1.659 g/cm^3 when adding 8 and 10%, respectively, as in Figure 5.

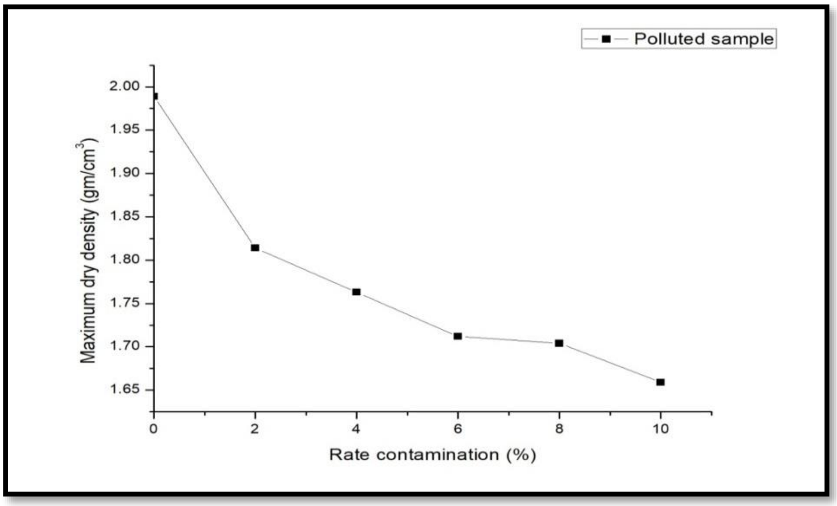

Figure 5: Maximum dry density values after adding different percentages of crude oil.

The natural sample had an optimal moisture content of 13.5%, however adding different proportions of crude oil caused the value of the optimum moisture content to rise. These findings also show that as the amount of crude oil grows, so does the ideal moisture content. The optimum moisture content increased to 16.2% with a 2% addition of crude oil and to 21.3% with a 10% addition, as shown in Figure 6. Because of the crude oil material's filling of the voids in the soil and the large spaces between its grains, which allow the oil to flow through them as easily as water and have a lubricating effect that causes the grains to slide over one another and lower density, the maximum dry density decreased. The rise in oil content is the cause of the increase in the ideal moisture content.

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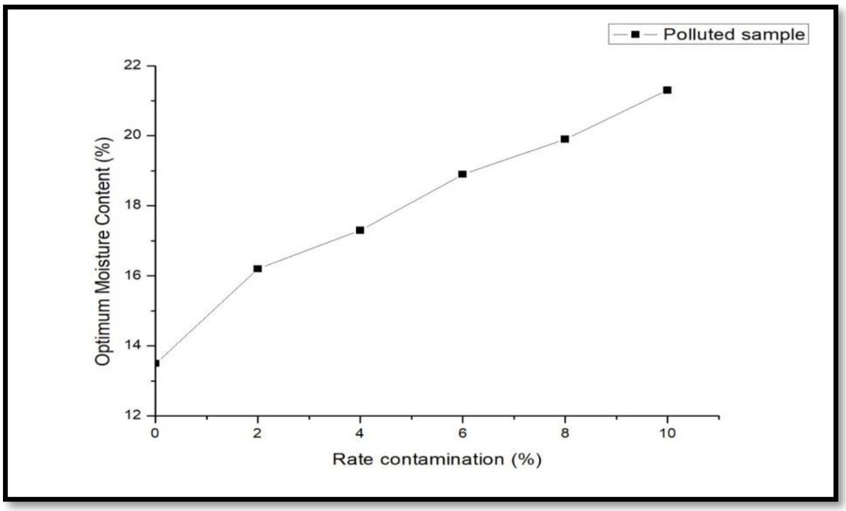

Figure 6: Optimum moisture content values after adding crude oil.

California bearing capacity: The results show that the value of the submerged California bearing capacity of the sample in its natural state is 19%. The optimum water content value was used to determine the CBR value when adding the crude oil material in different proportions, which are 2%, 4%, 6%, 8%, and 10%. The value of the submerged CBR significantly decreased, as evidenced by Figure 7, which shows that the CBR value dropped to 2% when 10% crude oil was added.

When the crude oil is added to the soil samples, it fills the soil pores and leads its grains to slide over one another resulting a reduction in the soil resistance, which explains the fall in the California bearing ratio data. California's bearing capacity is declining because of the decrease in the maximum dry density value caused by the increase in crude oil content.

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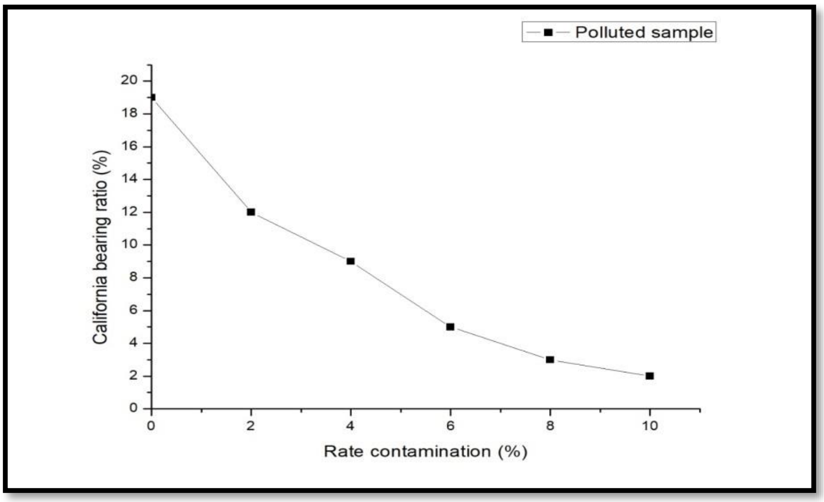

Figure 7: California bearing ratio values before and after adding crude oil.

In summary, the variation in the geotechnical properties of the examined North Rumaila soil before and after adding different percentages of crude oil is illustrated in Table 2. It can be clearly seen that the added crude oil has gradually reduced the angle of internal friction and maximum dry density (MDD), while it is highly decreased the California bearing capacity (CBC). Regarding the optimum moisture content (OMC), it is highly increased after adding crude oil. Overall, the contamination of the silty sand soils with crude oil has an adverse impact on its geotechnical characteristics.

Table 2: The geotechnical properties of the North Rumaila soil before and after adding different percentages of crude oil.

Geotechnical properties	Before adding oil	After adding oil				
		2%	4%	6%	8%	10%
Angle of internal friction (%)	33	32	31	31	30	29
OMC (%)	13.5	16.2	17.3	18.9	19.9	21.3
MDD (gm/cm^3)	1.989	1.814	1.763	1.712	1.704	1.659
California bearing capacity (%)	19	12	9	5	3	2

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CONCLUSIONS

The results indicate that the soil at the North Rumaila site has a moisture content of 6.45% and is mostly composed of silty sand with trace amounts of clay and gravel. Crude oil was added to the soil, which resulted in a decrease in the bearing capacity of California, an increase in the optimum moisture content, a decrease in the angle of internal friction, and a decrease in the value of the maximum dry density. These changes negatively impacted the soil's geotechnical characteristics.

Conflict of interests

There are non-conflicts of interest

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الخلاصة

يعد تلوث التربة بالمشتقات النفطية إحدى المشاكل التي تواجه التربة المقرر إنشاء المنشآت الهندسية في مواقع حقول النفط عليها. يحدث هذا التلوث بسبب بعض التسربات النفطية في مواقع استخراج وتكرير النفط، وكذلك نتيجة نقله بالمركبات أو عبر خطوط الأنابيب الناقلة. من الضروري إجراء دراسات حول تأثير التلوث بالنفط الخام على الخواص الجيوتكنيكية للتربة في مواقع التسرب حيث أن هذه التسربات، كما هو الحال في العديد من مواقع حقول النفط في محافظة البصرة، تؤثر بشكل كبير على الخواص الجيوتكنيكية للتربة الملوثة. تم اختيار موقع شمال الرميلة لإجراء الدراسة. وعلى عمق متر واحد تم استخراج تربة طبيعية خالية من التلوث وإضافة نسب وزنية 2، 4، 6، 8، و10% من الزيت الخام. تم إجراء التحليل الحجمي للحبيبات، ومحتوى الرطوبة، والقص المباشر، والدحل، وفحص التحمل الكاليفورني. تشير النتائج إلى أن التربة في موقع شمال الرميلة تحتوي على نسبة رطوبة تبلغ 6.45% وهي رمل غريني مع كميات صغيرة من الطين والحصى. أدت إضافة النفط الخام إلى التربة إلى تقليل قدرة التحمل الكاليفورني، وزيادة المحتوى الرطوبي الأمثل، وانخفاض زاوية الاحتكاك الداخلي، وإضعاف سعة تحميل التربة. وقد أثرت هذه التأثيرات سلباً على الصفات الجيوتكنيكية للتربة.

الكلمات المفتاحية: التلوث النفطي، تربة البصرة، الخواص الجيوتكنيكية، تربة الرميلة الشمالية، التحليل الحجمي.