Polytechnic Journal

Polytechnic Journal

Volume 8 | Issue 2 Article 20

5-1-2018

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How to Cite This Article

Aziz ARBILI, Mohamed Moafak and KARPUZCU, Mehmet (2018) "Effect of Crude Oil Contamination on physical and Chemical Properties of Soil of Tarjan Refineries Erbil Province - North of Iraq," *Polytechnic Journal*: Vol. 8: Iss. 2, Article 20.
DOI: https://doi.org/10.25156/ptj.2018.8.2.216

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Abstract

This paper presents the results of a study on the effect of crude oil contamination on the physical and chemical properties of soils of Tarjan refineries Erbil province, north of Iraq. A laboratory investigation was conducted to compare selected physical and chemical properties of uncontaminated and contaminated soil. Crude oil was chosen as the contaminant from khormala oil well in Erbil province. The effect of contamination by crude oils on the physical and chemical properties of soils has been studied. The testing included basic properties, Atterberg limits, Specific gravity, composition chemical and pH value on clean and contaminated soil samples. The contaminated samples were prepared by mixing the soils with crude oil in the amount of 3%, 6%, 9%, 12%, and 15% by dry weight. The results indicated an increase in liquid limit from 0% oil to 15% oil content were 35 to 55 respectively, specific gravity decreased with increasing oil contamination from clean soil was 2.663 to 15% oil content was 2.376, for the chemical properties the chemical composition slight decrease such MgO, Al2O3, CaO and Fe2O3 and increase such as Na2O with increasing the percentage of contaminant in the soil

Polytechnic Journal: Vol.8 No. 2 (May 2018): Pp:159-170

http://epu.edu.krd/ojs/index.php/Journal

Effect of Crude Oil Contamination on physical and Chemical Properties of Soil of Tarjan Refineries Erbil Province - North of Iraq

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ABSTRACT

This paper presents the results of a study on the effect of crude oil contamination on the physical and chemical properties of soils of Tarjan refineries Erbil province, north of Iraq. A laboratory investigation was conducted to compare selected physical and chemical properties of uncontaminated and contaminated soil. Crude oil was chosen as the contaminant from khormala oil well in Erbil province. The effect of contamination by crude oils on the physical and chemical properties of soils has been studied. The testing included basic properties, Atterberg limits, Specific gravity, composition chemical and pH value on clean and contaminated soil samples. The contaminated samples were prepared by mixing the soils with crude oil in the amount of 3%, 6%, 9%, 12%, and 15% by dry weight. The results indicated an increase in liquid limit from 0% oil to 15% oil content were 35 to 55 respectively, specific gravity decreased with increasing oil contamination from clean soil was 2.663 to 15% oil content was 2.376, for the chemical properties the chemical composition slight decrease such MgO, Al_2O_3, CaO and Fe_2O_3 and increase such as Na_2O with increasing the percentage of contaminant in the soil.

Key words: ***Crude oil contamination, Physical and Chemical properties, Laboratory tests, clayey soil.***

INTRODUCTION

Crude oil is a naturally occurring complex mixture of hydrocarbons. During the process of exploration, transportation, refining mid storage, crude oil may be spilled on soils. There have been some reports of accidents in oil wells which is also a cause of crude oil spill into the soil. On reaching the ground, these oil flow under gravity and contaminate die soil on its pathway.

Of late, several researchers as Adejumo (2012), Akinwumi et al (2014) and Gupta et al (2016) have diverted their work to study the effect of crude oil contamination on the engineering and chemical properties of soil. It is also reported by these investigators that crude oil contamination has a serious effect on some of the engineering and chemical properties of soil. These effects of crude oil on soils are to be taken into account for the proper design of structure on crude oil contaminated soils. Due to inadequate or poor knowledge of the properties of crude oil contaminated soil, there have been some reports of failure of structures constructed on crude oil contaminated soil (Yaji et al., 1995), Contamination of soil by crude oil in India is a major concern considering the huge network of oil pipelines that transport crude oil to and from various refineries (Bhattacharya 2004). An accidental release of petroleum products amounting to 240 million gallons (approx.) during the gulf war (1991) alone which represents the largest petroleum release event since record began to be kept consistently from 1978 (Srivastava et al. 2005). Hence, it is observed that leakage, spills or accident in the oil well is unavoidable. The spilled or gushing oil moved down to the groundwater under gravity. The soil is partially saturated by the oil on its pathway. After reaching the groundwater, the liquid has spread horizontally by migration within the capillary zone (Shroff 1997). This may lead to serious soil contamination. The petroleum hydrocarbons/ wastes released on the ground ultimately find its way to the soil system changing the properties of pore fluid.

A critical environmental impact of the petroleum industry is the spillage of oil and related products that may cause severe soil contamination. Oil contamination on the water is relatively easy to collect and remedy. However, soils are contaminated with oil the process is much longer and there may be significant environmental and engineering effects. For this reason, it is very important to investigate the properties of oil-contaminated soils.

The present study is a trial to determine the effects of the crude oil on the geotechnical properties liquid limit (LL), plastic limit (PL), specific gravity (SG) and pH value, artificially contaminated on silty clay soil of low compressibility (ML) collected from Tarjan refineries near Erbil province in Iraq. Different levels of contamination of crude oil have been chosen for this purpose.

STUDY AREA

Oil spillage in the Erbil province north of Iraq has become a public concern as a result of its frequent occurrence which has been linked with Petroleum exploration and transportation crude oil by pipe line and tankers also producing crude oil derivatives form refiners all those steps reason to polluted soil and contaminated. Crude oil spill affects plants negatively by creating conditions which makes essential nutrients like nitrogen, Oxygen etc. needs for plant growth unavailable to them from the spilled affected soil. Therefore, the purpose of this study is to evaluate the effects of oil spillage on soil properties in these areas.

The materials obtained from the study area are the soil sample (disturbed). The study area is the site of Tarjan refineries. The geo referencing coordinates of the site, GPS coordinates, are 36°08'04.3"N 43°46'02.2"E as shown in Figure. 1. Soil sample used to measure the effects of crude oil on some mechanical properties of soil.

Figure 1. Illustrait Satellite image of site the soil sample obtained from Tarjan refineries

MATERIALS AND EXPERIMENTAL WORK

Soil

Soil used in this study is a brown coloured, low plasticity clay soil (CL) which was collected from a borrow pit of 1 m depth below the existing ground level.

Crude Oil

The crude oil used for this purpose was procured from Khormala oil field - Erbil province and it has the properties as shown in Table 1.

Table 1, Properties of crude oil from Khormala oil field

Sample	Flash Point	Density @	Specific	^{0}API	Dynamic

	^{0}C	25^{0}C(g/cm3)	Gravity @ 25^{0}C		Viscosity (Cp)
Khormala oil field	53	0.849	0.851	23.261	18.20

Laboratory tests

A sample was collected in jute bags, air dried and transported to the laboratory. It is then sieved through a 4.75mm IS sieve and divided soil samples into 5 portions. Oil crude was added to each of the portions at 0%, 3%, 6%, 9%, 12% and 15% by dry weight of soil sample. Soil-crude oil mixture was thoroughly mixed and stored in containers for two weeks for allowing possible reaction. After that, Atterberg limits, specific gravity, chemical composition and pH were tested. There is some limitation for the addition of more crude oil to the soil sample. Using more than 15 percentage of crude oil the soil tests are become difficult due to the looseness of the particles and draining off excess oil during compaction from the sample.

Basic properties of uncontaminated soil

Results of index properties on the uncontaminated soil are presented in Table 2. According to the Unified soil classification system (USCS) it is classified as clay of low plasticity clay (CL). Figure 2 graphically illustrates its particle size distribution.

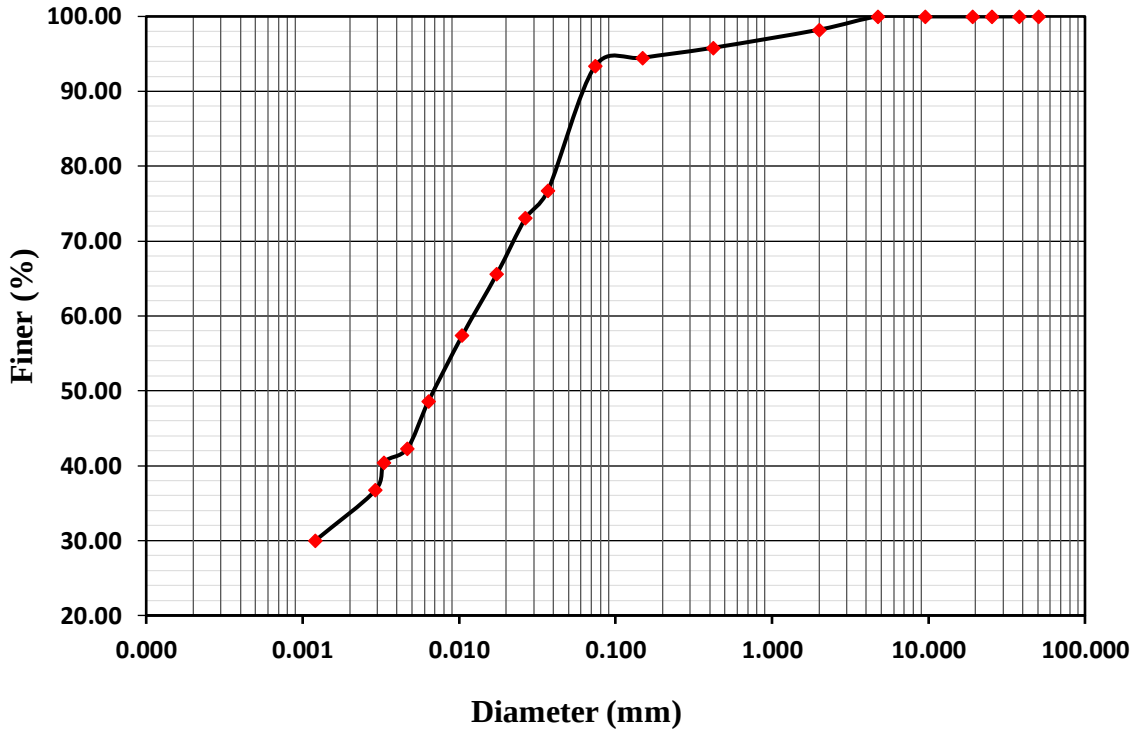

Figure 2. Illustrates the particle size distribution of soil sample

Table 2, Properties of the uncontaminated soil

Properties	**Value/Description**
Sand (0.075-4.75mm) (%)	7
Silt and Clay (<0.075mm) (%)	93
Unified soil classification system	CL- low plasticity clay
Colour	Brown
Organic content (%)	0.5
Specific gravity	2.663
Liquid limit (%)	35
Plastic limit (%)	21
Plasticity index (%)	14
Maximum dry unit weight	17.6
Optimum moisture content (%)	14
pH value	6.6

RESULTS AND DISSCUSSION

Effect of crude oil contamination on Atterberg limits of soil

In the figure 3 illustrated the variation of Atterberg limits for different % of crude oil. The liquid limit, plastic limits and plasticity index of the soil increase progressively with increase in crude oil content. Addition of crude oil to the soil creates a false increase in the thickness of diffused double layer, this may be responsible for the increase in the liquid from 0% oil to 15% oil content were 35 to 55 respectively. The test results supports observations made by Mitchell (1976) where it was mentioned that plastic limit of soil increases when organic matter is added to it. The plasticity index also increased with the increasing crude oil content. It demonstrated that, contaminated soil become less workable.

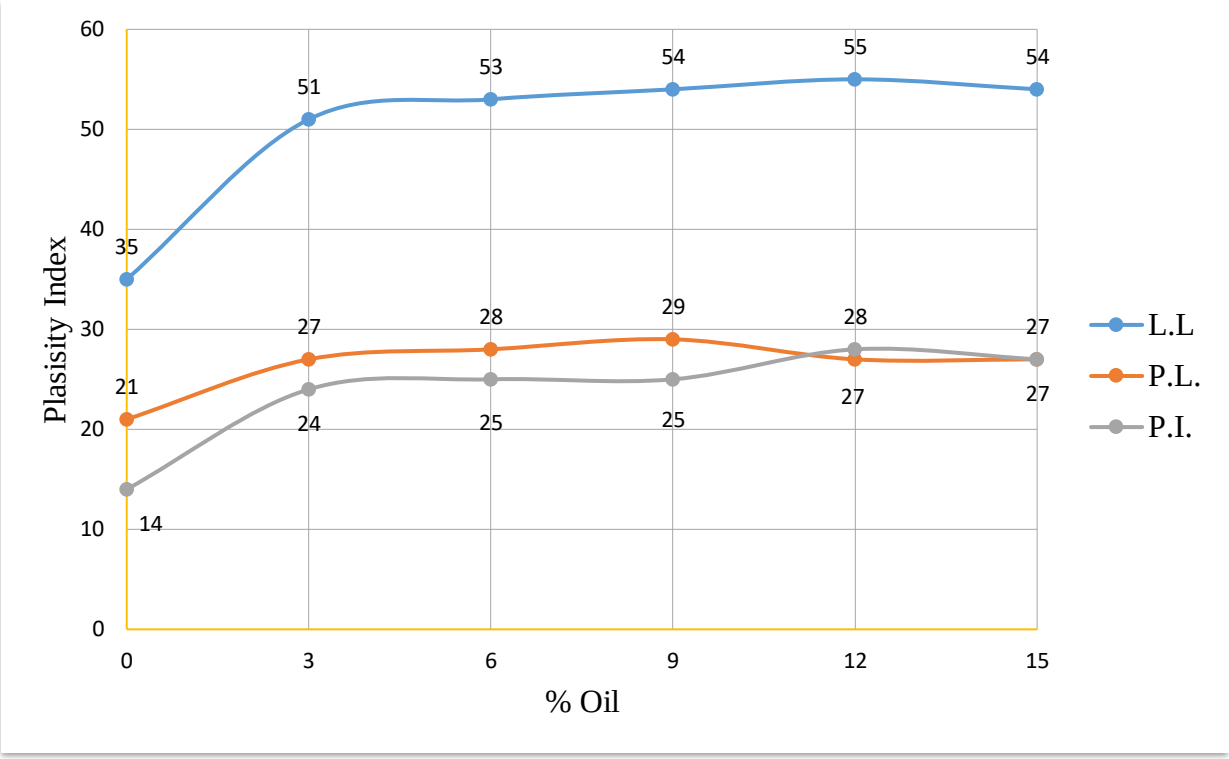

Figure 3. Illustrates the variation of Atterberg limits with oil content

Effect of crude oil contamination on specific gravity of soil

The specific gravity of the soil sample is 2.663. A graphical presentation of the variation of specific gravity of the soil with the crude oil content in the soil is shown in Figure. 4. As the percentage of crude oil admixed with the soil sample increased, the specific gravity of the mixture decreased. This is attributed to the lower specific gravity of the crude oil.

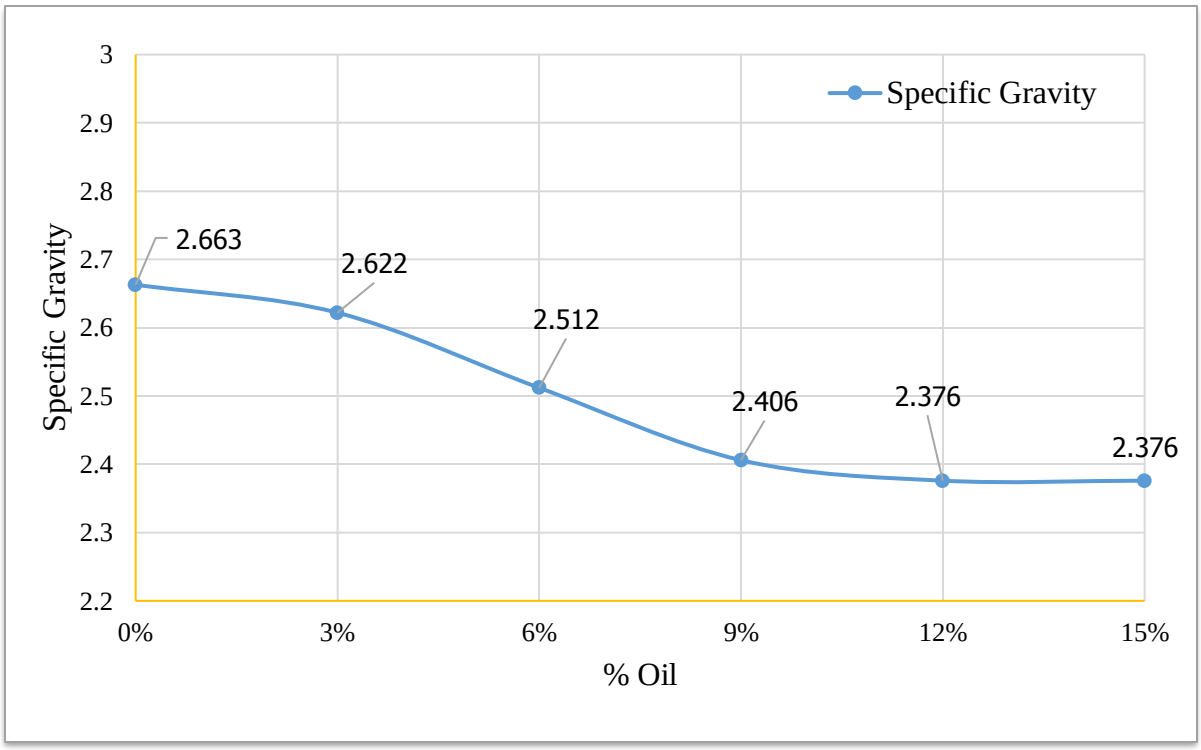

Figure 4. Illustrates the effecting crude oil of specific gravity

Effect crude oil contamination on chemical composition of soil

The chemical compositions of the clean soil and contaminated were determined using X-ray fluorescence (XRF) analyses in terms of oxides. The geochemical characterization of the soil was determined using spectrophotometer (X-Supreme8000) as shown in figure 5

Figure 5. Illustrates the XRF analysis (X-ray fluorescence) by spectrometer X-Supreme8000

The chemical compositions of the clean soil shown in figure 6

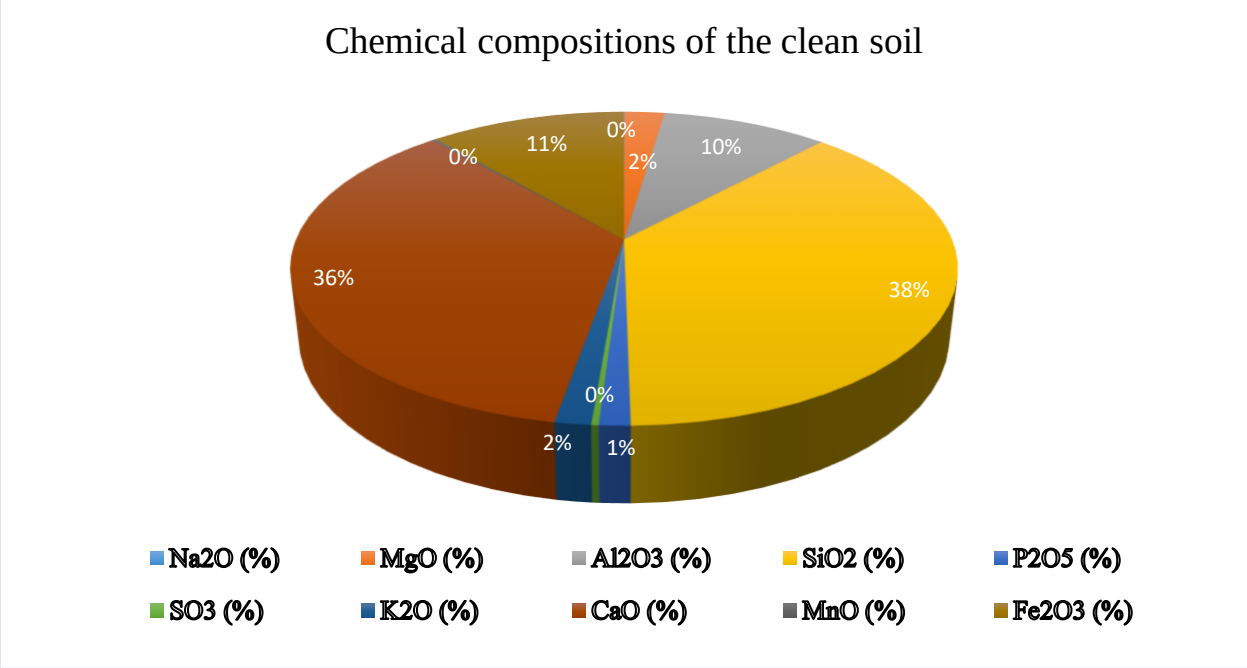

Figure 6. Illustrates the Chemical compositions of the clean soil

Some of the chemical composition slight decrease such MgO, Al2O3, CaO and Fe2O3 and increase such as Na2O with increasing the percentage of contaminant in the soil, The sulfur trioxide decreased by 5 % and 10 % in the soil samples with the 3% and 15% contamination respectively. The chemical reactions between the mineralogical composition of soil and crude oil sulfate ion which causes decrease the percentage of sulfur trioxide. Also, the crude oil causes increasing the accumulative of exchangeable bases such as Na or Ca in the soil which resulted in a reduction in the exchangeable acidity and affect the cations exchange capacity.

Table 3, Results of chemical composition tests of uncontaminated and contaminated soil

Element (%) / %Oil	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	MnO	Fe_2O_3
0 %	0.018	1.372	5.685	22.327	0.75	0.178	0.872	21.071	0.132	6.717
3 %	0.024	1.346	5.468	21.273	0.631	0.257	0.862	20.371	0.129	6.769
6 %	0.042	1.358	5.572	21.649	0.749	0.316	0.877	20.469	0.128	6.799
9 %	0.052	1.412	5.109	21.567	0.557	0.22	0.833	20.185	0.133	6.75
12%	0.058	1.258	5.149	20.322	0.666	0.352	0.803	19.936	0.130	6.668
15%	0.046	1.535	5.582	20.192	0.553	0.293	0.74	19.498	0.127	6.512

Effect crude oil contamination on PH value of soil

Crude oil contamination increased pH values as a shown in figure 8. The soil pH values in all samples with different ratio of contamination were up to 7.75 and were significantly higher than that in the control. The results of previous studies on effect crude oil on pH value showed that oil pollution raised soil pH (Jia et al., 2009; Wang et al., 2010), which is supported by our results. The higher pH values in crude oil-polluted soil in this study might be caused by two factors: first, the hydrophobic nature of crude oil might induce a potential drought in the surface and subsurface layers of polluted soil (Njoku et al., 2009), which could aggravate salinization, and thus raise the pH values compared with that in the control; second, oil contamination in soil has been shown to be associated with the accumulation of exchangeable base (such as Ca2+, Na+) and a reduction in exchangeable acidity and effective cation exchange capacity (ECEC) (Benka-Coker and Ekundayo, 1995; Ekundayo and Obuekwe, 1997; Osuji et al., 2006; Agbogidi et al., 2007). These mechanisms might also underpin the increase of pH values in the crude oil contaminaion soil.

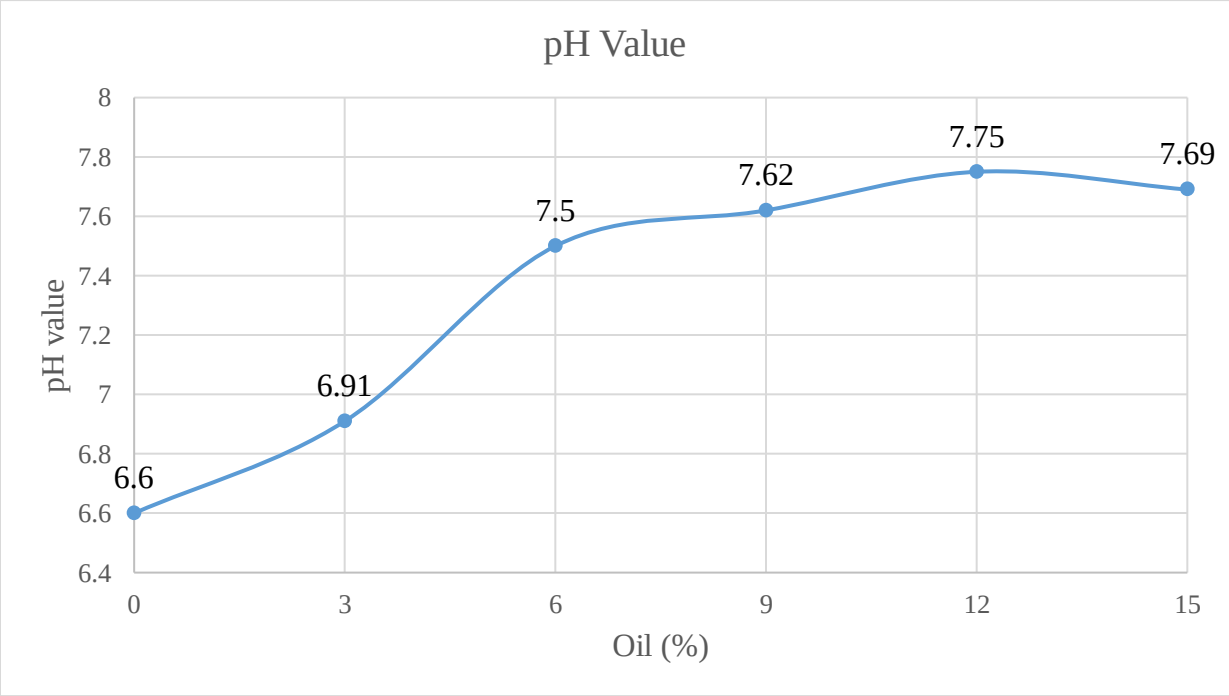

Figure 8. Illustrates effect crude oil contamination on PH value of soil

CONCLUSION

It can be concluded that the test results obtained from this study, the main conclusions are as follows:

- Addition of crude oil to the soil resulted in an increase in the liquid limit, plastic limit and plasticity index of the contaminated soil. This was attributed to the increase in the

thickness of the diffuse double layer. Increased plasticity indicates that contamination of the soil made the soil less workable.

- The specific gravity decreased as the crude oil content in the soil increased.
- For the chemical properties, the chemical composition slight decrease such MgO, Al_2O_3, CaO and Fe_2O_3 and increase such as Na_2O with increasing the percentage of contaminant in the soil
- The pH value increased as the crude oil content in the soil increased.
- How crude oil contamination affects the interactions between soil chemical factors has not been resolved in this study, which will be studied in the future.

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