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Experimental Approach for Treatment of Contaminated Soil with Crude Oil

Taha Ibadalden Abdulkarim[1*], Ali Hasan Abdulla[2]

[1] Fuel and Energy Technologies Engineering Department, Technical Engineering College, Northern Technical University, Mosul 42002, Iraq
[2] Petroleum Engineering Department, Faculty of Engineering, University of Kirkuk, Kirkuk 36001, Iraq

Corresponding Author Email: tahaabdulkarim@ntu.edu.iq

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ABSTRACT

Oil is considered one of the most dangerous sources of environmental pollution, especially for the soil, as it turns it into sterile soil that is not suitable for animal, plant or any living thing. Therefore, in this research, we will use four methods to treat soil contaminated with crude oil, where animal and plant fertilizers were used at rates of 20% and 40% in each method, with both types active and inactive, on samples of contaminated soil, after preparing these samples they were compared with each other by analyzing the data and the results of scientific experiments held on the samples. Where the results of the treatment of contaminated soil, and by using some of these methods, showed an increase in the ratio of bacteria beneficial to the soil and at the same time an increase in the ratio of organic materials feeding the plant, because of the existence of types of bacteria in these fertilizers that eliminate or feed on the toxic oil compounds that exists in the soil, in addition to this activating and providing the soil again with bacteria that are beneficial to it. After we applied the treatment processes and scientific experiments, it became clear that the method (B1) using animal fertilizer (sheep manure) after adding a quantity equal to 40% of the sample gives the most positive result when treating soil contaminated with crude oil.

1. INTRODUCTION

The crude oil is transported through the pipelines transporting for long distances, and most often these pipes pass through agricultural lands. In term of this long distance transform, leakage may occur in these pipes leads to soil pollution. Oil pollution may alter the chemical and physical properties of soils. This research deals with the treatment of soil contaminated with crude oil in which there was a leak of crude oil in order not to negatively affect plant growth and agricultural production. The soil gets rid of toxic compounds present in crude oil without affecting the physical properties of the soil. Contaminated soil is treated using animal droppings and plant leaves. Pore spaces may become clogged, reducing soil aeration and water infiltration while also increasing bulk density, affecting plant growth [1]. Oils with a higher density than water have the potential to reduce and restrict soil permeability. Crude oil contamination raises the pH of the soil to 8.0 and reduces the amount of phosphorus available in the soil. Total organic carbon concentrations differ significantly between sampling sites [2]. As a result, crude oil contamination could alkalinize marsh soils, affecting soil fertility and physical properties, and causing marsh degradation. Crude oil is a complex mixture of hydrocarbon compounds, non-hydrocarbon compounds and small quantities of minerals not more than 5 percent [3, 4]. Crude oil consists of the elements of carbon (83-87 percent), hydrogen (10-14 percent), sulfur (0.05 to 6.0 percent), oxygen (1.5 percent), nitrogen (0.1 percent) in addition to heavy metals such as vanadium, mercury, cadmium, nickel, and others in small quantities [5]. The fragile or fragmented surface layer that covers the Earth's surface is known as soil. The soil is made up of fragmented rock materials that have changed as a result of exposure to environmental, biological, and chemical factors, such as weathering and erosion. It is worth noting that the soil differs from its basic rock components, which is the reason for its change in the interactions that occur between the four shells of the earth's surface; they are the lithosphere, hydrosphere, atmosphere and biosphere [6]. Soil is a mixture of the organic and mineral components that make up the soil in its liquid(water)and gaseous(air)states. That is, as the materials that make up the soil retain among their loose particles porous gas (or so-called soil pores) and thus form the soil structure that these pores fill. These pores include aqueous solution(liquid)and air(gas). Soil scientists can envisage soils as a three-state system of solids, liquids, and gases [7]. Hydrocarbon compounds conclude paraffin which they are largely circular, oils and aromatic which considered toxic compounds and also conclude other toxic compound [8], and the proportions of these components vary from crude oil to crude oil depending on the reservoir's geological formation. The occurrence of a leak in the pipelines transporting the crude oil will be a reason that it is not possible to grow in these lands again because the oil contains chemical compounds that are toxic to the bacterial organisms beneficial to the soil and the plant, in addition to that there are some compounds within the crude oil that are in the form of oils that work to block pores For the soil, it prevents the flow of water and air necessary to feed the plant and the soil, so the soil must be treated as quickly as possible ,or else it damages will not only conclude the plants

but also the animals and humans and all the living matter. Color, texture, structure, porosity, density, consistence, temperature, and air are all physical properties of soil [9]. Soil colors vary greatly, indicating important properties such as organic matter, water, and redox conditions. The types of soil particles and their arrangement are related to soil texture, structure, porosity, density, and consistence. The respiration of plant roots and microorganisms, as well as the transformation of mineral and organic matter, is greatly aided by soil air. A soil test provides information on the chemical properties of a soil. The levels of various nutrient elements in our sample, as well as soil pH, buffer pH, cation exchange capacity, base saturation, organic matter, soil nitrogen, soil salinity, Calcium carbonate content, and Calcium Sulfate (Gypsum)content, are all listed on the soil test report [10]. The pH value of a soil can be used to classify it, neutral 6.5 to 7.5), alkaline (over 7.5), acidic (less than 6.5), strongly acidic (PH less than 5.5) and strongly alkaline (PH more than 8.5) [11]. The North Oil Company of the government of Iraq, in partnership with the Iraqi Ministry of Health and Environment, launched a pilot project in Kirkuk for biological treatment aimed at enhancing the ability of nature to remove oil spills with the United Nations Environment Program, and with the support of the United Nations Assistance Mission for Iraq (UNAMI). The initiative seeks to harness soil bacteria that grow naturally as a strong ally to remove toxic oil pollutants from polluted soil. Microbes (bacteria and fungi) that naturally disintegrate provide a promising and cost-effective solution to Iraq's oil pollution problems. Also, a Kuwaiti Researcher Dr. Mishary Saad Al-Mutairi has developed an environmentally friendly way to treat soils contaminated with oil derivatives and petroleum hydrocarbons. The new method aims to separate oil pollution from the soil, at a rate that the researcher said exceeds 90% at a low cost, and by washing the soil. What distinguishes Al-Mutairi's new method is its uniqueness by treating contaminated soils using water and sound waves through environmentally-friendly equipment without the use of heat or chemicals. The method of washing the soil with water and sound waves does not need to add organic or chemical substances to separate the oil deposits. It is based on mixing the polluted soil with water and sending sound waves, which form electric charges that carry out the task of separating the oil deposits from the soil [12]. The best results were in samples (B1, B2). Continuing to stir the soil and spraying it with water and exposing the samples to sunlight and keeping them in a warm place increases the percentage of bacteria in the soil. Thus, it feeds and rid the soil of toxic compounds and turns them into organic compounds that are useful for plants, meaning that the proportion of organic compounds inside the soil increases relatively after treatment processes.

2. MATERIALS AND THE LABORATORY MEASUREMENTS

We bring about (kg 3) of the soil and put it in a container, then put about(700ml) of crude oil in the container that contains the soil and mix it until the soil is saturated with crude oil and repeat the process for three days [13], after that, we put the contaminated soil in small bottles where each bottle will contain (250g) of soil. The treatment processes are divided into four methods. The first method using animal fertilizer (bird manure- active type), the second method using animal fertilizer (sheep manure- inactive type), the third method using planet fertilizer (peat moss- inactive type), and the fourth method using planet fertilizer (eucalyptus leaves- active type). Fertilizer is added with different proportions for each method, the first proportion is to add an amount equal to (20%) of the soil weight in the bottle(50g), and the second proportion is to add an amount equal to (40%) of the weight of the soil in the bottle (100g).

The ninth sample will be just contaminated soil without any treatment components. Also, we made a sample from the soil that is not contaminated with crude oil in order to compare its experimental results with the results of the samples that exposure to the treatment processes. It must be mentioned that every two days all of the contaminated samples are subjected to the stirring up process, water spraying and we put them under the sun for about three hours in the day so the bacteria that live inside the soil get enough air and get fermented quickly. After preparing all the ten samples we make symbols for every one of them in order to distinguish them as showing in the Table 1.

Table 1. Symbols of each treatment sample

No.	Symbol	The sample type
1	A1	40% birds manure- active type
2	A2	20% birds manure- active type
3	B1	40% sheep manure- inactive type
4	B2	20% sheep manure- inactive type
5	C1	40% planet fertilizer (peat moss)- inactive type
6	C2	20% planet fertilizer (peat moss)- inactive type
7	D1	40% planet fertilizer (eucalyptus leaves)- active type
8	D2	20% planet fertilizer (eucalyptus leaves)- active type
9	E1	Contaminated soil without any treatment
10	E2	Clean soil without crude oil

After six months of treatment processes on the samples we start the laboratory measurements in order to check the soil properties and check the results of the treatment processes by making some experiments and these experiments include thermal cracking [14], PH measurement of the soil [15], the biological growth experiment [16, 17], the salinity measurement of soil، seeds planting [10].

3. RESULT AND DISCUSSION

3.1 Thermal cracking experiment

It can be seen clearly in Table 2 and Figure 1 that in samples (A1) and (A2) (birds manure 40% and 20) the ratio of the amount of hydrocarbon compounds are high because the treatment process has failed, (B1) and (B2) samples (sheep manure fertilizer 40% and 20%) the amount of hydrocarbon was good and its organic good hydrocarbon compound for soil, we can assure that from the planting results, C1 and C2 samples(plant Fertilizer (peat moss) 40% and 20%)the hydrocarbon amounts are higher than animal fertilizer because already the peat moss fertilizer has a lot of organic compounds inside the peat moss parts in the fertilizer, (D1) and (D2) samples (eucalyptus leaves 40% and 20%) these samples gave the highest results and the amount of hydrocarbon was very high because of the presence of small eucalyptus leaves parts inside the soil that get burned during the thermal process,

while the (E1) sample (contaminated soil without treatment process) the amount of hydrocarbon was high and that because of the existence of hydrocarbon compound inside the sample.

Table 2. Results of amount of hydrocarbon in 10 g of samples

No.	Symbol of the sample	hydrocarbon amount in 10 g
1	A1	1.83 g
2	A2	1.35 g
3	B1	1.54 g
4	B2	1.21 g
5	C1	1.73 g
6	C2	1.46 g
7	D1	2.26 g
8	D2	1.83 g
9	E1	1.61 g
10	E2	1.04 g

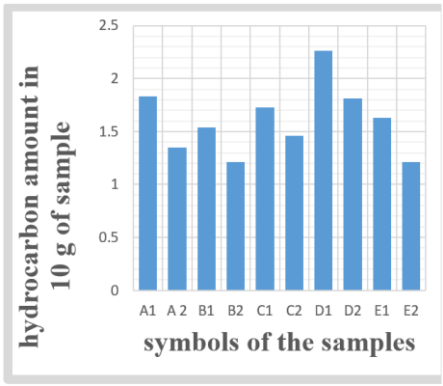

Figure 1. Diagram of the results of thermal cracking experiment

3.2 PH measurement of the soil

Table 3. The PH value of each sample

No.	Symbol of sample	The PH value
1	A1	5.1
2	A2	5.4
3	B1	6.6
4	B2	6.1
5	C1	5.4
6	C2	5.7
7	D1	5.6
8	D2	5.8
9	E1	5.9
10	E2	5.2

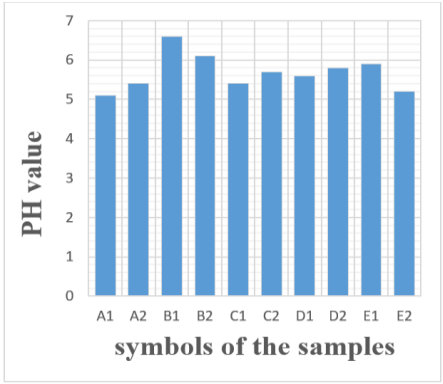

Figure 2. Diagram of the results of PH experiment

The urea made PH value in the samples (A1) and (A2) lower, the sheep manure fertilizer increased the PH value of soil to about 6.6 in (B1) and 6.1 in (B2) and in general it's a good PH value for soil. pH value of the samples (C1, C2) become lower than PH of (E1) and (E2) samples because the peat moss fertilizer made the PH of the soil lower, The PH value of the samples (D1, D2) become slightly lower than the PH value of (E1) sample because the eucalyptus leaves are slightly acidic and gave it effect on the sample, while PH value in the sample (E1) become higher from the (E2) sample because crude oil hydrocarbon compounds make the PH higher (see Table 3 and Figure 2).

3.3 The biological experiment

Cover the lower half of the Petri dish with the warm nutrient-agar mixture for bacteria, then take 5 gm of soil sample like powder and hold it in a clean collection and place it in the Petri dish containing the agar mixture and cover with the lid, then put the Petri dish for about 24-48 hours in incubation at 25 degrees Celsius. After 24 hours, we can clearly see the agar that has grown inside the dish in the form of circles through a microscope (Compound Microscope), which is evidence of bacterial growth (see Table 4 and Figure 3) The urea killed the bacteria in the samples (A1, A2), because bird droppings contain urea. we can see that from the results of the biological experiment. However, the high amount of funguses in the biological experiments is a clue that the fermenting process of bacteria in the samples (B1, B2) was successful, and we can see that the bacterial growth in the samples (C1, C2) is good. In addition, it is obvious that bacteria were grown in samples (D1, D2) very good because they convert Phytotoxic hydrocarbons compounds into organic compounds, which are useful for the soil.

Table 4. The percentage of agar existence in petri dish of each sample

No.	Symbol of sample	The percentage of funguses existence at petri dish of each sample
1	A1	25%
2	A2	35%
3	B1	90%
4	B2	80%
5	C1	75%
6	C2	60%
7	D1	80%
8	D2	70%
9	E1	30%
10	E2	65%

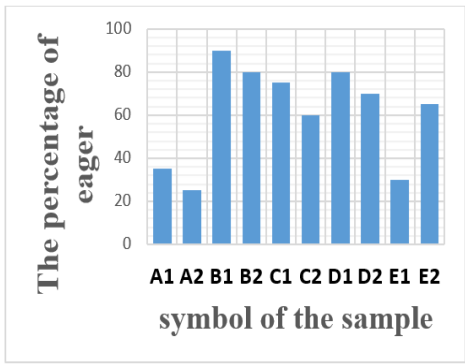

Figure 3. Diagram of the percentage amount of eager in 10 g of sample

3.4 The salinity measurement of the soil

Table 5 and Figure 4 show the bird manure components that made the salinity of the samples (A1, A2) higher than the salinity of the original sample(E2)because the salt content was high in the bird manure, and decreased in samples (B1, B2) because of the existence of compounds like(phosphate, potassium)in the sheep manure, but The salinity of the sample (C1, C2, E1) becomes lower than the salinity of the (E2) sample because of the repeated water spraying and increasing the amount of soil due to the addition of treatments, while The salinity of the samples (D1, D2) was very high because the eucalyptus leaves save an amount of salt inside it.

Table 5. The salinity of each sample in ds/m

No.	Symbol of sample	The salinity of 10 g of soil in ds/m
1	A1	0.61
2	A2	0.58
3	B1	0.47
4	B2	0.503
5	C1	0.51
6	C2	0.517
7	D1	0.63
8	D2	0.603
9	E1	0.53
10	E2	0.57

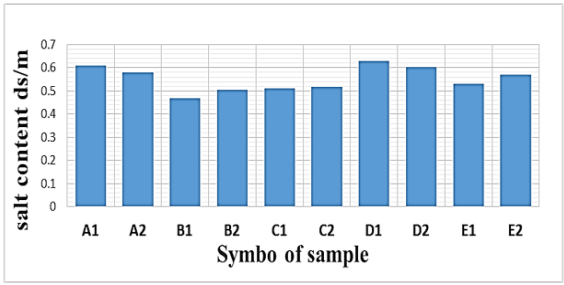

Figure 4. Diagram of salt content of samples

3.5 Planting the seeds

Table 6. The planets number of each sample in in 5 cm^2 area

No.	The samples symbol	The number of plants in 5 cm^2 area
1	A1	failed
2	A2	failed
3	B1	47
4	B2	39
5	C1	31
6	C2	18
7	D1	34
8	D2	23
9	E1	14
10	E2	36

The high concentration of urea in samples (A1, A2) prevents the seeds from growing, while the most number of plants has grown in the samples (B1, B2) even more than sample (E2) sample (the sample of soil without crude oil) and that means that the samples (B1, B2) not only treated from contaminated oil but also it becomes better than the soil that is not contaminated with crude oil. The plants number at samples (C1, D1) was almost to the plants number of sample (E2) it means that the treatment process was also successful and the percentage of the number of plants in the samples (C2, D2) was greater than the sample (E1) (see Table 6 and Figure 5).

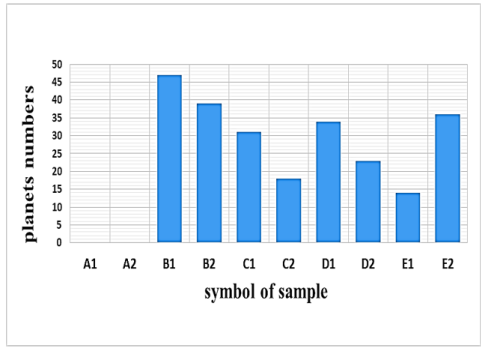

Figure 5. Diagram of number of planets in 5 cm^2 area of each samples

4. CONCLUSION

The best results are in the (B1, B2) samples and the best treatment process is using the animal fertilizer (sheep manure) with adding an amount equal to 40% of the sample weight, We also note that the samples (C1, C2, D1, D2) gave good results and treatment processes with using plant fertilizer (peat moss) and (eucalyptus leaves) and they gave results close to the result of the sample (E2), while the samples (A1, A2) has failed because of the existence of high concentrations of urea that killed the bacteria inside the sample. We also note that continuing to stir the soil, spraying it with water, exposing the samples to sunlight and keeping them in a warm place is very important because it increases the speed of the bacteria fermentation process inside the soil. As a result, the beneficial ratio of organic compounds in treatments soil are greater than the sample (E2), because the bacteria convert compounds Phytotoxic into organic compounds useful for the soil. In the future, the research will be conducted on samples of contaminated soil, but by adding chemical fertilizers (NPK) and industrial urea.

REFERENCES

[1] Abosede, E.E. (2013). Effect of crude oil pollution on some soil physical properties. Journal of Agriculture and Veterinary Science, 6(3): 14-17.

[2] Wang, Y., Feng, J., Lin, Q., Lyu, X., Wang, X., Wang, G. (2013). Effects of crude oil contamination on soil physical and chemical properties in Momoge wetland of China. Chinese Geographical Science, 23(6): 708-715. https://doi.org/10.1007/s11769-013-0641-6

[3] Pulkrabek, W.W. (2004). Engineering fundamentals of the internal combustion engine. Journal of Engineering for Gas Turbines and Power, 126(1): 198-198. https://doi.org/10.1115/1.1669459

[4] Rodríguez-Antón, L.M., Gutiérrez-Martín, F., Martinez-Arevalo, C. (2015). Experimental determination of some physical properties of gasoline, ethanol and ETBE ternary blends. Fuel, 156: 81-86. https://doi.org/10.1016/j.fuel.2015.04.040

[5] Hyne, N.J. (2001). Nontechnical Guide to Petroleum Geology, Exploration, Drilling, and Production. Tulsa, OK: Penn Well Corporation. ISBN: 978-1-59370-269-4.

[6] Chesworth, W. (Ed.). (2007). Encyclopedia of soil science. Springer Science & Business Media. ISBN 978-1-4020-3994-2.
[7] McCarthy, D.F., McCarthy, D.F. (1977). Essentials of soil mechanics and foundations. Reston: Reston Publishing Company. http://sutlib2.sut.ac.th/sut_contents/H109094.pdf.
[8] Walters, P., Khan, S., O'Brien, P.J., Payne, J.F., Rahimtula, A.D. (1987). Effectiveness of a Prudhoe Bay crude oil and its aliphatic, aromatic and heterocyclic fractions in inducing mortality and aryl hydrocarbon hydroxylase in chick embryo in Ovo. Archives of Toxicology, 60(6): 454-459. https://doi.org/10.1007/BF00302389
[9] Bowers, S.A., Hanks, R.J. (1962). Specific heat capacity of soils and minerals as determined with a radiation calorimeter. Soil Science, 94(6): 392-396. https://doi.org/10.1097/00010694-196212000-00007
[10] Läuchli, A., Epstein, E. (1990). Plant responses to saline and sodic conditions. Agricultural Salinity Assessment and Management, 71: 113-137.
[11] Wu, L., Zhang, S., Wang, J., Ding, X. (2020). Phosphorus retention using iron (II/III) modified biochar in saline-alkaline soils: Adsorption, column and field tests. Environmental Pollution, 261: 114223. https://doi.org/10.1016/j.envpol.2020.114223
[12] Al Mutairi, M.S. (2016). Development and evaluation of a remediation strategy for the oil lakes of Kuwait Doctoral dissertation, University of Portsmouth. https://researchportal.port.ac.uk/en/studentTheses/development-and-evaluation-of-a-remediation-strategy-for-the-oil-.
[13] Enweani, I.B., ODIA, A. (2005). Bioremediation of soil polluted with crude oil. Built Environment, 1(2): 151-160.
[14] Abánades, A., Ruiz, E., Ferruelo, E.M., Hernández, F., Cabanillas, A., Martínez-Val, J.M., Rubio, J.A., López, C., Gavela, R., Barrera, G., Rubbia, C. (2011). Experimental analysis of direct thermal methane cracking. International Journal of Hydrogen Energy, 36(20): 12877-12886. https://doi.org/10.1016/j.ijhydene.2011.07.081
[15] Brown, T.T., Koenig, R.T., Huggins, D.R., Harsh, J.B., Rossi, R.E. (2008). Lime effects on soil acidity, crop yield, and aluminum chemistry in direct-seeded cropping systems. Soil Fertility & Plant Nutrition, 72(3): 634-640. https://doi.org/10.2136/sssaj2007.0061
[16] Ochoa-Hueso, R., Delgado-Baquerizo, M., King, P.T.A., Benham, M., Arca, V., Power, S.A. (2019). Ecosystem type and resource quality are more important than global change drivers in regulating early stages of litter decomposition. Soil Biology and Biochemistry, 129: 144-152. https://doi.org/10.1016/j.soilbio.2018.11.009
[17] Oosterbaan, R.J. (1988). Effectiveness and Social/Environmental Impacts of Irrigation Projects: A critical review. ILRI Annual Report, 1988: 18-34. https://waterlog.info/pdf/irreff.pdf.