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Treating Drill Cuttings Waste with Oil Contamination by Microwave Treatment then by Earthworms Technique

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Abstract

In this research paper, two techniques were used to treat the drill cuttings resulting from the oil-based drilling fluid. The drill cuttings were taken from the southern Rumaila fields which prepared for testing and fixed with 100 gm per sample and contaminated with two types of crude oil, one from Rumaila oilfields with Sp.gr of 0.882 and the other from the eastern Baghdad oilfield with Sp.gr of 0.924 besides contamination levels of 10% and 15% w/w in mass .Samples were treated first with microwave with a power applied of 540 & 180 watts as well as a time of 50 minutes. It was found that the results reached below 1% w/w in mass, except for two samples they reached below 1.5% w/w in mass .Then, the sample of 1.41% w/w in mass, which has the highest contamination level after microwave treatment, was treated on three groups of earthworms. After the appropriate conditions, samples were prepared for treating by earthworms and for an incubation period of 21 days, the results highlighted the effectiveness of the succession process by reaching concentrations below 0.92%, 0.65%, and 0.42% w/w in mass.

Keywords: Drill cuttings waste, Microwave treatment, oil Contamination, Earthworms treatment

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1- Introduction

Waste disposal operations from the oil and gas industry, unexpected accident leakage, or improperly disposing of drilling waste, have quite serious consequences for human health and the environment in general. When contaminated drill cuttings are removed with the remaining drilling fluids, especially with oil-based mud (OBM), the chemical fractions of liquids begin to seep into the ground, causing the elimination of existing organisms and contaminated groundwater [1]. Normally, the remains of the drilling mud (whether it was oil-based mud or water-based mud) and the drill cuttings are associated with the presence of various hydrocarbon concentrations and heavy materials. The saturated and unsaturated hydrocarbon concentrations are greater in the oil-based mud, these concentrations can reach about 50% and this percentage is more than that in water-based mud (WBM). Accordingly, it is more toxic than WBM [2].

Since the disposal of drilling waste had become a global problem that causes escalating anxiety, especially for researchers and oil companies, due to the multiple negative impacts on public and environmental health [3], oil and gas wells drilling in Iraq cannot be an exception in this manner. Drilling waste produced by the exploration and production industry is coming in the second place of international ranking for the largest volume of waste produced [4].

The waste disposal problem has become an important point in achieving a good environmental management system. In general, contamination of drilling fluids with drill cuttings waste is an inevitable result of successful drilling operations; therefore, drill cuttings waste accumulation ought to go through the treatment and disposal option after all. In that situation of the drill cuttings that need to be handled earlier to disposal, there are numerous feasible selections including land-farming, bioremediation, solidification, thermal desorption, stabilization, and cuttings re-injection [5], etc. Land reclamation is a regularly utilized bioremediation strategy in which the oil-contaminated drill cuttings are applied to the land where evaporation synchronically with the natural organisms of the soil combines to diminish the pollution of the waste [6], [7].

Among these ways, bioremediation can be considered as a well-proven and environmentally acceptable technology that employs microorganisms (i.e. bacteria, fungi, and or earthworms) to biologically eliminate oil contaminated waste into nontoxic remnant and reduce contaminant concentrations to acceptable levels. Vermiculture or worms farming is a well-steady technique for remediating organic wastes and decompose them into a material eligible for receiving essential nutrients to increase flora growth [8]. Earthworms are an important indicator of soil health, as their presence means the quality of the soil and its absence means the opposite [9], [10].

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Earthworms are also a good predictor of toxicity measurement and have been used to assess environmental risks [11][12] [13]. However, scientific information remains limited about the sensitivity of earthworms to contaminated soil, as well as their viability and mechanism of treating the soil [14][12]. Several important studies have highlighted the activity of earthworm use to promote hydrocarbon contaminant loss from soil [15][16].

On the other hand, microwave drying is one of the modern technologies used industrially and at home, which showed effective results in its practical applications and brought about an ever-increasing change with drying various materials [17] [18]. The treatment levels accomplished by the microwave drying process were significantly greater than those used in the solid control system [19] [20].

The microwave technique is a treatment method for handling waste of many kinds and has multiple advantages. It is also easy to use and fast to accomplish, as well as it can be controlled remotely and with great flexibility. Furthermore, the microwave can reach the required temperature in less than 1% of the time required by traditional heating methods. Besides, the microwave technique is preferred as it considered to be a source of clean energy [21] [22] [23]

The application of a microwave oven, which can be used on-site, is one of the high gain methods in terms of the process of greatly reducing pollution levels that meet the legal requirements for treating and storing waste, unlike the usual methods whose results are almost satisfactory. However, a successful microwave treatment requires a lot of knowledge or experience to understand the effect of uneven heating of constituent or thermal leakage. The other side of the disadvantages of this treatment is the need for electrical energy, which is one of the most expensive forms of energy, as the microwave oven requires energy with a thin layer to apply waste penetration [24] [25]. The approach used in this study tries to reach close to zero discharge concept of oil contamination in waste solids, a combination of microwave treatment and earthworm technique will be discussed.

2- Experimental Work

2.1. Fundamental Materials

a. Drill Cuttings

The drill cuttings, which have been used in this study, were collected from South Al-Rumaila oilfield pits as shows in Fig. **1**. The waste drill cuttings obtained from the Al-Rumaila waste pit were the result of the formation which has been drilled and the remaining separating water-based mud. As a result, the drill cuttings are needed to be prepared before the treatment. Therefore, the drill cuttings had been treated in a microwave oven by applying maximum power applied for 24 hours to get rid of the water and organic contents.

Then, pure samples were taken from the drill cuttings and fixed at (100 gm weight) and crushed to have a size of grain (5-10 mm) for each sample as shown in Fig. **2**.

Fig. 1. Drill cutting of South Al-Rumaila oilfield pits

Fig. 2. Weight of prepared sample of drill cuttings

b. Hydrocarbon Specification

Two types of hydrocarbon were taken. The first type of crude oil was taken from the reservoir of South Al-Rumaila oilfield in Basra before it goes to clarify impurities and the other one was taken from Eastern Baghdad oilfield in Baghdad after the treatment from the impurities.

The hydrocarbon's specific gravity of the South Al-Rumaila oilfield was measured (Sp.gr=0.882). Whereas the hydrocarbon's specific gravity of Eastern of Baghdad oilfield was (Sp.gr=0.924).

c. Microwave Device

The Specifications of the Microwave device were of model No. of GMO-330; inputs of 50 Hz and 1400-Watt; the output of 2450 Hz, maximum of 900 Watt and selective power applied and GRILL of 1100 Watt as shown in Fig. **3**.

Fig. 3. Microwave device used in this study

d. Earthworms selection

An earthworm called "Allolobophora" was used for treatment. The selected earthworms are Allolobophora, have the following bio classification: Phylum: Annelida, Class: Oligochaeta, Order: Opisthopora [26]. The average weight of these earthworms is (2.2gm) and their average length is (3 cm).

2.2. Experimental Set-up

a. Microwave Treatment

Three parameters were taken; the power applied was (180 and 540 Watt), the hydrocarbon concertation was (10%, and 15% w/w in mass) for two kinds of hydrocarbon as mentioned before with specific gravity (0.882 and 0.924). The period of treatment was (50 min) dividing by four times which is (10, 20, 30, and 50 min).

b. Earthworms treatment

After the microwave treatment was finished, it was noticed that only one sample was (1.41% w/w in mass) and the others below or about 1% of contamination. As a result, the parameters were taken according to that to reduce the pollution (1% w/w in mass) or less. Three groups of earthworms were taken (5, 10, and 15 in counts).

The duration of the experiment was 21 days divided into 3 weeks, and the treated hydrocarbon concentrations were examined at the end of each week.

The treated drill cuttings, with 1.41% w/w in mass were prepared by adding (50% w/w in mass) of fertile soil that came from the same source of the obtained earthworms. Neutron food (Carrots, Cabbage, and waste of slaughterhouse) was added by (20% w/w in mass) to the total weight, taking into account the addition of fertilizer as a ratio (25:1) of Nitrogen to phosphor to each sample [26] as is shown in Fig. **4**.


Fig. 4. Earthworms treatment sample

3- Analytical Method

3.1. Microwave Analysis

The process of analyses to monitor the progress in decreasing the oil contamination was checked using the electronic balance instrument. At first, a glass container weight was calculated for each sample. Then, the polluted drill cuttings were weighted and since the drill cuttings weight is fixed at 100 gm, the formula that represented the remain of hydrocarbon concentration is as follow:

$$W_n = W_{t(n)} - (W_{hydi} + W_{con} + W_{cut}) \quad (1)$$

Where:

W_n= The remaining weight of hydrocarbon after any time in gm unit.

W_{hydi}= The initial weight of hydrocarbon before treatment in gm unit .

W_{con} = weight of glass container in gm unit.

W_{cut}= Weight of fixed drill cuttings which is 100 gm.

$W_{t(n)}$= The total weight at any period of hydrocarbon contamination, drill cuttings of 100 gm, and their container in gm unit.

3.2. Earthworm Analysis

The process of analyzes was done by taking (1 or 3 gm) of the sample, considering it represented the entire sample, and it is added to a tube containing (3 or 9 ml) of a solvent called n-Hexane.

After that, the Vertex device performed a shaking and mixing process for three minutes in preparation for the Centrifuge device so that the hydrocarbons are separated from the solvent and the drill cuttings well using the principle of different densities. One milliliter of hydrocarbons is taken and injected into the Gas-chromatography device to maintain the results.

4- Results and Discussions

4.1. Microwave Treatment Results and Discussion

It appears from Table **1** and Table **2** the concentrations decreased with the increase of time.

Table 1. Treating Drill Cutting with power applied 180 Watt

Time in min.	Concentration of Sp. Gr. 0.882	Concentration of Sp. Gr. 0.882	Concentration of Sp. Gr. 0.924	Concentration of Sp. Gr. 0.924
0	10%	15%	10%	15%
10	9.12%	14.79%	9.21%	14.83%
20	7.25%	13.5%	7.01%	13.62%
30	1.78%	10.71%	1.47%	9.23%
50	0.62%	1.41%	0.49%	1.01%

Table 2. Treating Drill Cutting with power applied 540 Watt

Time in min.	Concentration of Sp. Gr. 0.882	Concentration of Sp. Gr. 0.882	Concentration of Sp. Gr. 0.924	Concentration of Sp. Gr. 0.924
0	10%	15%	10%	15%
10	8.79%	14.55%	8.13%	14.68%
20	1.57%	11.58%	1.34%	11.07%
30	1.02%	7.32%	0.94%	7.19%
50	0.47%	0.91%	0.41%	0.83%

Tables above show that the relationship between time and the decrease of concentrations is a direct correlation.

In general, as shown in Fig. **5** and Fig. **6** below when the power applied is increased the contamination dropping increases in which fluid reduction increased and drying time was shortened by raising microwave power in which microwave ovens can transfer energy to the entire substance, as the energy affects the internal structure. This will cause higher energy acting on the internal structure when the power applied increased [27].

Moreover, when the concentration of the hydrocarbon in drill cuttings is less, the treatment reaches less than 1% much faster. Furthermore, microwave penetration faces difficulties when the concentration of oil contamination in drill cutting increases. For that reason, for concentration (10% w/w in mass) in the first ten minutes, the decreasing in contamination is not like the concentration in (15% w/w in mass) when the thickness of sludge layer of the sample inside Microwave chamber increased the penetration of microwave takes longer time to achieve the drying process [27], [29].

Despite increasing the power applied in the microwave treatment to increase the speed of reducing hydrocarbon concentrations can only be useful till about 35-40 minutes as it shows that from 35-40 minutes till fifty minute the decrease in oil contamination is relatively slow.

The study attributes the relatively slowly in decreasing of concentration in the last fifteen minutes to the residue of high-density compositions 'in which the microwave has difficulty in treating them' that remain after the evaporating of the light compositions.

Besides that the range of specific gravities which is taken, shows the regular type of crude oil obtained from Iraqi oil fields and that will lead to a conclusion which is the difference in specific gravities does not affect directly the concentration decreasing when the microwave is used for treating a drill cutting with oil contamination (obtained from Iraqi reservoir).

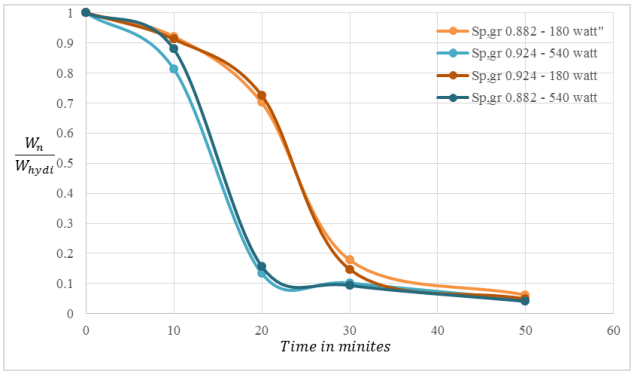

Fig. 5. Oil contamination reduction of 10% w/w in mass with time

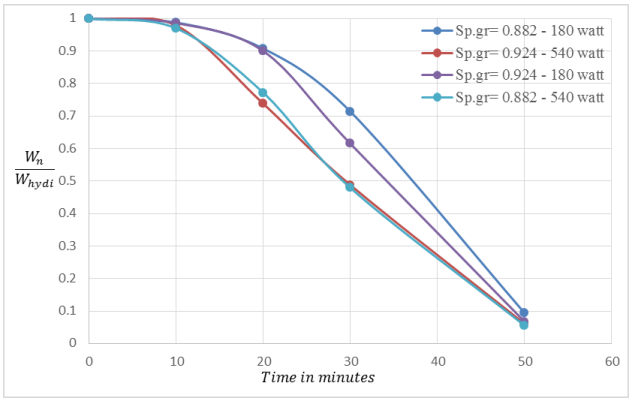

Fig. 6. Oil contamination reduction of 15% w/w in mass with time

4.2. Earthworms Treatments Results and Discussion

Table **3** shows the reduction in contamination of hydrocarbon when time is passing through.

Table 3. Earthworm's treatment on the treated oil of 0.882 Sp. Gr

Time in days	Concentration with 5 Earthworms in w/w in mass	Concentration with 10 Earthworms in w/w in mass	Concentration with 15 Earthworms in w/w in mass
0	1.41%	1.41%	1.41%
7	1.23%	1.08%	0.91%
14	1.06%	0.86%	0.61%
21	0.92%	0.65%	0.42%

When the earthworm's numbers increase the treatment of the polluted drill cuttings increased [26]. It appears that the concentrations decreased after 21 days. Also, it reveals that the decreasing increase with the time increment.

The treatment showed great effect and this indicates that treatment with earthworms after microwave treatment recorded success.

In general, reaching such results not even reached below the international regulation but for many countries reached better than the target of environmental treating as for US Environmental Protection Agency (US EPA) stated that discharged cuttings cannot be greater than (6.9% by mass) for the organic pollution of synthetic fluid adhered. Besides, In the United Kingdom and European Union, the discharge regulation compliance obliges a limit of less than 5.5% of organic content and 1% of oil on cuttings [1], [30].

5- Conclusion

The application of the two techniques together leads to the possibility of reducing the power applied by the microwave as well as reducing the range of time in its work, which reduces the consumption side of electrical energy. The same applies to biological treatment by earthworms in terms of numbers and days of monitoring. Less than 1% w/w in a mass of oil pollution can be reached from 15% w/w in mass and may approach zero discharge with increasing the incubation period of earthworms treatments.

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معالجة مخلفات الفتات الصخري ذو التلوث النفطي بواسطة جهاز المايكروويف ومن ثم بتقنية ديدان الأرض

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الخلاصة

تم استخدام طريقتين بالتتابع لمعالجة الفتات الصخري الملوث نفطيا من اجل إيجاد حل لمشاكل التلوث جراء الحفر بسائل الحفر ذو الأساس النفطي. حيث أُخذت عينات الفتات الصخري من حقول الرميلة الجنوبي وتم تحضير العينات وتثبيت وزن كل عينة بـ 100 غم لأغراض التجربة، واخذت عينتان من النفط أحدهما من حقول الرميلة الجنوبي بكثافة نوعية 0.882 والأخرى من حقل شرقي بغداد بكثافة نوعية 0.924. أيضا تم تلويث الفتات الصخري بنسب 10% و15% من التلويث النفطي بنوعيه. وكانت نتائج تجربة المايكروويف الذي تم استخدام قوة مسلطة فيه 540 و180 واط ناجحة حيث وصلت نسبة التلوث النفطي الى ما دون الـ 1% لجميع العينات عدا عينتان ما دون الـ 1.5% بمدة قدرها 50 دقيقة لكل عينة. بعدها تم اخذ اعلى تركيز لعينة تمت معالجتها من قبل المايكروويف بمقدار 14100 وتحضيرها لفحص مدى قدرة ديدان الأرض على معالجة التلوث المتبقي وكانت مدة الحضانة 21 يوم لثلاث مجاميع من ديدان الأرض 5 و10 و15 وكانت نتائج التلوث قد انخفضت الى ما دون ال 0,05% منذ التلوث البدائي مما يدل إمكانية معالجة مشكلة التلوث النفطي عند استخدام سائل الحفر ذو الأساس النفطي وما يشاكله.

الكلمات الدالة: الفتات الصخري، معالجة بالمايكروويف، معالجة بديدان الأرض، التلوث النفطي.