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Research Paper

Contaminant Removal in Soil and Wash Water Residue from Ex-Mining Area in Jambi using Soil Washing Remediation

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Abstract

Soil washing is an effective method to remove contaminants from contaminated soil through the process of transferring it from the solid phase to the liquid phase. The increase in petroleum exploration activities in Jambi Province requires processing efforts so that the waste produced does not contaminate the environment. This study aims to analyze the removal of pollutants from petroleum-contaminated soil using the soil-washing process and the use of fixed bed column to remove contaminant from wastewater generated by the soil-washing process. This study examined the effect of soil washing using Tween 80 surfactant on the concentration of Total Petroleum Hydrocarbon (TPH) in petroleum-contaminated soil at the Ex-Mining Area in Jambi and the removal of oil and grease in soil washing residue using a fixed bed column with coffee husk biochar medium. The soil washing method used a leaching column with various concentrations of Tween 80 surfactant solution of 0.5% (v/v) and 1% (v/v). In addition, leaching was repeated 0, 1, and 2 times. Coffee husk biochar was used as a medium in a fixed bed column to remove oil and grease from soil-washing residue with thickness variations of 10 cm, 20 cm, and 30 cm. The results showed that the soil was loamy sand with an initial TPH content of 3092.75 mg kg^{-1}. The soil-washing process reduced the TPH concentration with a removal efficiency of 72.45-90.40%. The highest TPH removal occurred in one leaching repetition at a 0.5% surfactant concentration. The optimum oil and fat removal from the use of a fixed bed column was at 30 cm thickness which was 94.35%.

Keywords
soil washing, wash water residue, fixed bed column, petroleum-contaminated soil, coffee husk biochar

1. INTRODUCTION

The need for petroleum is increasing from time to time along with the high demand for energy as a result of technological advances and the needs of human life, so the process of exploration and exploitation of petroleum is increasing which causes various environmental contamination problems, especially illegal oil drilling activities or commonly known as illegal drilling (Effendi and Indriati, 2015). Environmental problems caused by petroleum drilling are soil contamination by oil spills and pipe leaks in certain amounts, areas and conditions will be trapped in soil pores/soil particles. The oil fraction can evaporate into the air mixed with soil and groundwater, so special treatment is needed to separate the oil from the medium, namely soil. Separation of petroleum from soil can be done by various methods, one of which is soil washing using the leaching method (Harmesa, 2020).

Soil flushing is an alternative method that can be implemented economically due to low energy requirements. This method can remove various types of contaminants in soil depending on traditional chemical and physical extraction processes, soil contaminants that can be removed using this method such as oil & gas, Total Petroleum Hydrocarbon (TPH), heavy metals, and cyanide (Tiwari and Tripathy, 2023). The remediation process using a leaching column requires the addition of chemicals in the form of surfactants. Surfactants have polar and nonpolar groups in one molecule. One side will bind oil (nonpolar), and on the other side, the surfactant will bind water (polar).

In this study, the leaching process using Tween 80 surfactant aims to remove TPH in petroleum-polluted soil. In previous research by Khan et al. (2004), the leaching method has an efficiency of approximately 90% in separating oil spills trapped in the soil so that it can restore the function and condition of soil polluted by oil spills. After the soil washing process is carried out, it will produce a residue in the form of wash water. Most of the fine fraction of contamination has been released from the soil and suspended in the water. In contaminated soil, there are various kinds of nutrients both organic and inorganic that can experience distribution to the wash water during the soil washing process (Aulia and Effendi, 2020). This wash water contains fatty oil compounds derived from petroleum-polluted soil and also surfactant compounds used in the washing process. If disposed of directly, it can cause contamination to the environment so processing efforts are needed.

The utilization of biochar in wastewater treatment is quite widely researched because it has high effectiveness in reducing polluting parameters. biochar can reduce contaminants from wastewater both containing metals and nonmetals (Ahmed et al., 2016). Biochar contains high carbon (C) which is more than 50%. biochar does not undergo further weathering so when applied as water filtration it will last a long time, biochar also has high mechanical strength and porosity which greatly supports biochar being used as an adsorbent (Nelson, 2020).

2. EXPERIMENTAL SECTION

2.1 Soil Washing Process

The research was conducted at the Engineering Laboratory of Batanghari University. Testing of TPH content in soil samples was carried out at the Integrated Research and Testing Laboratory of Gadjah Mada University (LPPT UGM) and testing of oil and grease content in soil washing residue was carried out at the Jambi Provincial Environmental Service Laboratory.

2.1.1 Soil Sampling

Sampling of petroleum-contaminated soil was carried out in one of the former petroleum mining sites located in Bungku Village, Bajubang District, Batanghari Regency, Jambi Province. Soil samples were taken using a disturbed sampling technique.

2.1.2 Preparation of Wash Solution

The wash solution was made by adding Tween 80 as much as 0 ml, 15 ml, and 30 ml into 3000 ml of distilled water. The variation of Tween 80 concentration as wash solution in the soil washing process is 0% (v/v), 0.5% (v/v), and 1% (v/v).

2.1.3 Remediation Procedure

The remediation stage on a laboratory scale is carried out using a leaching column reactor (Figure 1). The remediation process includes the following stages (Effendi & Indriati, 2015):

- The oil-contaminated soil is dried at room temperature until the moisture content reaches ±5%.
- The soil granules are then released by hand and stirred until homogeneous.
- 600 grams of homogenized contaminated soil is put into a leaching column with a diameter of 2.7 inches.
- A predetermined concentration of surfactant solution flows into the leaching column in a downward flow direction.

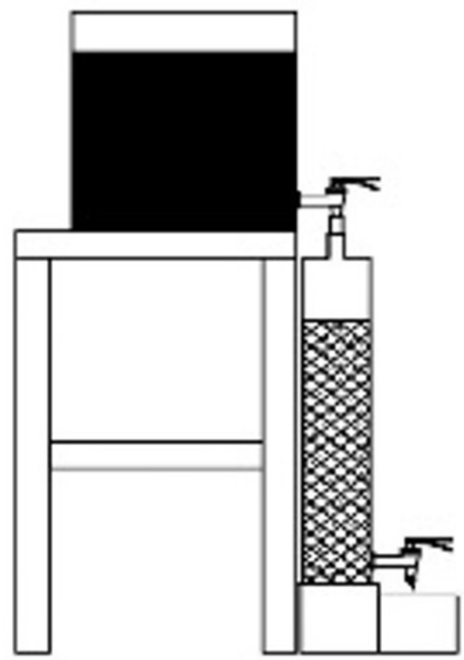

Figure 1. Leaching Column Reactor Components: Surfactant Solution Container (A), Petroleum Contaminated Soil (B), Soil Washing Residue Container (C)

- Repetition of flowing is done in variations, namely 0, 1, and 2 times.
- The soil that has been flowed is then removed from the leaching column and dried again at room temperature for TPH analysis.

2.2 Treatment of Soil Washing Residue

Processing of soil-washing residue was carried out on a fixed bed column. The media used was biochar from coffee husk synthesized through a carbonization process at 350°C. Variations in the amount of biochar used was measured based on the thickness of the media in the fixed bed column. The stages of soil washing residue processing are as follows:

- Soil washing residue previously generated from the soil washing process had been collected in a holding container.
- A certain amount of biochar was put into a fixed bed column reactor with a diameter of 2.7 inches. The variation of biochar media thickness is 10 cm, 20 cm, and 30 cm.
- Soil washing residue was put into the fixed bed column reactor and collected again for oil and grease content testing.

3. RESULT

4. RESULTS AND DISCUSSIONS

4.1 Contaminated Soil Particle Size Distribution

Sieve analysis and hydrometer tests were conducted to determine the particle size distribution of petroleum-contaminated soil. The soil sample contained 81.92% sand, 15.34% silt, and 1.74% clay. The USDA classification system showed that the oil-contaminated soil from Bungku Village was a type of loamy sand.

4.2 Effect of Surfactant Concentration on Soil Total Petroleum Hydrocarbon Removal

The initial Total Petroleum Hydrocarbon (TPH) concentration in the soil was 3092 mg kg^{-1}. The addition of Tween 80 increased TPH removal by more than 70%. The use of Tween 80 as the surfactant in the soil washing process decreased TPH contaminants in the soil. The surfactant used at a concentration of 0.5% had a value above Tween 80 critical micelles concentration (CMC) of 5400 mg l^{-1}. The formation of micelles above the CMC increases the solubility of contaminants so that TPH contaminants are trapped in the hydrophobic core of the micelle by hydrophobic forces and as a result the solubility of TPH in the water phase increases.

A Tween 80 solution concentration of 1% removes less TPH contaminants than a Tween 80 solution concentration of 0.5%. This is because higher surfactant concentrations lead to excessive conditions and cause surfactant accumulation. Surfactant accumulation causes the emergence of micelles in large quantities and forces the molecules formed to get closer to each other and join. The interaction between oil and surfactant is easier to occur and in this case, there will be a lot of clumping (Mistry and Sarker, 2016). Based on the Tween 80 surfactant solution concentration variation, the largest TPH removal in loamy sand soil occurred using 0.5% surfactant concentration.

4.3 Effect of Leaching Repetition on the Removal of Soil TPH Contaminants

The effect of the removal of TPH contaminants with the addition of repetition time and the concentration of tween 80 surfactants of 0.5% has increased the removal to more than 80% as shown in Table 2.

Based on Table 2, repetition of leaching causes an increase in the removal of TPH in the soil. This increase occurs because the contact time between the surfactant solution and the soil is longer, allowing the tween 80 surfactant solution that does not bind contaminants in the first leaching, has the opportunity to bind contaminants to the soil particle fraction during the second leaching and so on.

The leaching variation without repetition resulted in an efficient contaminant removal of 87.69%. The one-time leaching variation resulted in a 3% increase in removal compared to no repetition. This is possible because the previous TPH contaminants did not fully experience contact with the tween 80 surfactant solution so the contaminants have not been removed completely. Two times repetitions of leaching only removed TPH to 84.90%. The decrease in TPH removal with repeated leaching may be due to TPH contaminants that have been bound by the Tween 80 surfactant solution being released back into the soil particles. Based on the variation of leaching repetition, the Tween 80 solution has the highest value of removal in the variation of one repetition. Repetition of leaching more than once causes oil that has been bound by surfactants to be reabsorbed into the surface of soil particles from particles that have been dispersed (Tiwari and Tripathy, 2023).

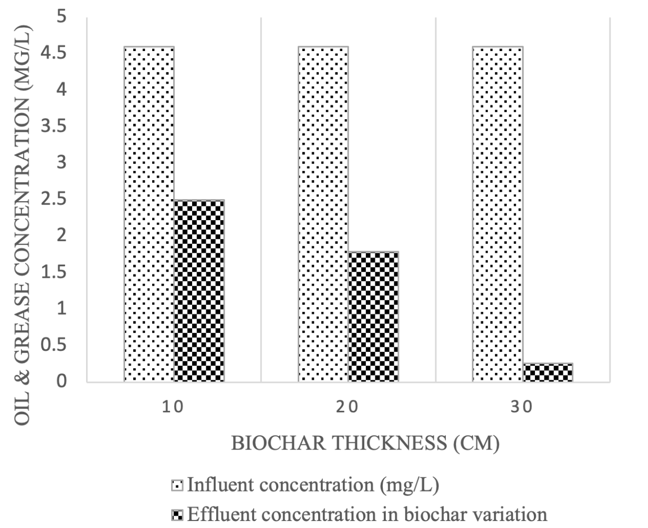

Figure 2. Oil and Grease Removal in Fixed Bed Column

4.4 Oil and Grease Removal in Soil Washing Residue

Table 3 shows that the thickness of the adsorbent in the fixed bed column affects the length of retention time in the soil-washing residue treatment process. The thicker the biochar, the longer the retention time required. At a thickness of 10 cm adsorbent requires a retention time of 20 seconds, at a thickness of 20 cm adsorbent requires a retention time of 150 seconds and a thickness of 30 cm requires a retention time of 210 seconds.

Based on Table 4 and Figure 2, it can be seen that the initial concentration of oil and grease parameters is 4.6 mg l^{-1} and after the adsorption process using coffee husk biochar adsorbents get results where the concentration of oil and grease parameters decrease with increasing biochar thickness, where sequentially at a thickness of 10, 20 and 30 cm to 2.5 (mg l^{-1}), 1.79 (mg l^{-1}) and 0.26 (mg l^{-1}). The removal efficiency of oil and grease is the highest reaching 94.35% at a biochar thickness of 30 cm (Figure 3). The removal value obtained is the level of adsorption by coffee husk biochar on soil-washing residue which is influenced

Table 1. TPH Removal using Various Surfactant Concentrations

Soil Sample	Tween 80 Concentration (%)	Final TPH Concentration (mg/kg)	Removal Efficiency (%)
1	0	3092.72	0
2	0.5	380.75	87.69
3	1	851.92	72.45

Table 2. TPH Removal by Repetition of Leaching

Soil Sample	Leaching Repetition (times)	Surfactant Concentration (%)	Final TPH Concentration (mg/kg)	TPH Removal (%)
1	0	0.5	380.75	87.69
2	1	0.5	296.79	90.40
3	2	0.5	467.09	84.90

Table 3. Retention Time of Wash Water Residue Treatment in Fixed Bed Column

Biochar thickness (cm)	Biochar Mass (gr)	Retention time (second)
10	146	20
20	295	150
30	340	210

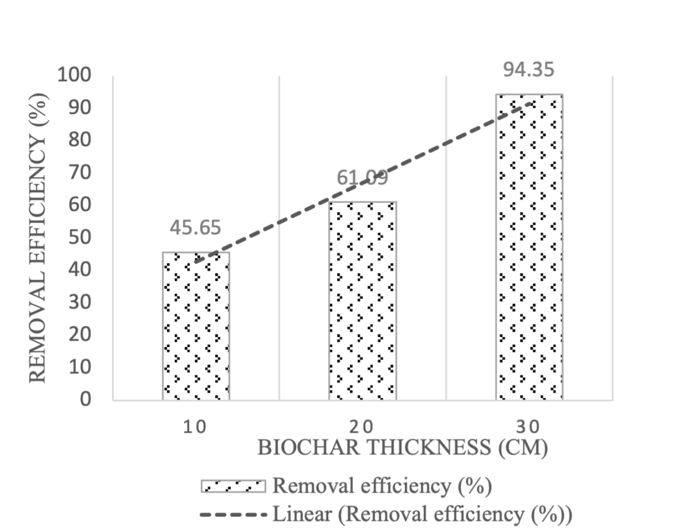

Figure 3. Removal Efficiency of Oil and Grease in Wash Water Residue

by the amount of biochar as an adsorbent and the contact time required during the flowing process. The greater the amount of adsorbent used, the contact time of soil washing residue against biochar will also increase. The amount of biochar and the length of contact time affect the level of pollutant adsorption to be higher. Therefore, in this study, the biochar thickness of 30 cm is very effective in reducing the concentration of oil and grease in soil washing residue.

Hidayat and Damris (2019) stated that increasing the biochar ratio increases the absorption ability due to the adequate amount of biochar accumulation so that it can absorb optimally due to greater mass transfer. According to Anwar et al. (2022), the adsorbent mass influences the amount of adsorbate adsorbed. An increase in adsorbent mass will provide more surface as adsorption sites. In general, the addition of adsorbent mass increases the sorption of pollutants which will increase the percentage of removal due to the increase in adsorbent contact time with the adsorbate so that the adsorption process can take place optimally. The same thing was also revealed by Aulia and Effendi (2020) where the adsorption of pollutants increases with increasing contact time.

5. CONCLUSION

In loamy sandy soil, the soil washing method using a leaching column with the addition of Tween 80 surfactants can reduce Total Petroleum Hydrocarbon (TPH) contaminants with a reduction efficiency of more than 70%. The variation of addition of Tween 80 surfactant concentration had the highest removal with a value of 87.69% at 0.5% surfactant concentration. The variation of leaching repetition and the addition of 0.5% concentration had the highest removal value with leaching repetition of 1 time with a value of 90.40%.

The use of coffee husk biochar for soil washing residue treatment in fixed bed columns was considered effective in removing oil and grease parameters. The removal efficiency value of oil and grease parameters is within the range of the final test results of 45.65% - 94.35%. Variation in the adsorbent thickness of coffee husk biochar influenced the removal of oil and grease parameters. The 30 cm adsorbent

Table 4. Oil and Grease Removal in Soil Washing Residue

Biochar thickness (cm)	Biochar Mass (gr)	Influent concentration (mg/L)	Effluent concentration (mg/L)	Removal efficiency (%)
10	146	4.6	2.5	45.65
20	295	4.6	1.79	61.09
30	340	4.6	0.26	94.35

thickness variation was more optimal in the removal of oil and grease with an efficiency of 94.35% and an adsorption capacity of 0.0077 mg l^{-1} compared to the 10 cm and 20 cm thicknesses. This indicates that increasing the adsorbent thickness allowed for greater mass transfer.

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