Remediation of diesel contaminated soil using chemical and biological surfactants

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ABSTRACT

Today, soil pollution by crude oil and its derivatives is of great importance, and it has become one of the serious environmental challenges in the world. This study aimed to remediate diesel-contaminated soil by enhancing the soil washing process using chemical and biological surfactants on a laboratory scale. For this purpose, the chemical surfactants of Triton X 100, SDS, and the synthesized natural surfactant of rhamnolipid were used. During this process, carried out in a Plexiglas column with an approximate volume of 400 ml, the effect of parameters such as surfactant concentration, solution pH, soil texture, flow direction, and pollutant concentration as independent variables on soil treatment was investigated. In this study, the maximum total petroleum hydrocarbons (TPH) removal efficiency of 78% from contaminated soil (containing 10% clay and contaminated with 10,000 mg / kg diesel) was achieved after 12 hours of soil washing using a combined surfactant of TX100-SDS (mixing ratio of 80:20 and a concentration of 5 g / L) with a flow rate of 1.5 mL / min at a pH of 7.8. Although in this research, rhamnolipid had a lower removal efficiency than other surfactants, due to its biodegradability and lower toxicity compared to other chemical surfactants used, as a potentially sustainable option to achieve efficient application and better effectiveness; it requires more investigation and research.

KEYWORDS

Soil Flushing, Bio Surfactant, Chemical Surfactant, Diesel, Soil Pollution

1. Introduction

Today, soil pollution by crude oil and its derivatives has been of great importance so it has become one of the main environmental challenges in the world. Due to the extensive nature of this problem, the cleaning of contaminated soils has priority, and it is necessary to investigate new methods to achieve high efficiency, less energy consumption, and lower cost. In this regard, soil washing is a process that uses a fluid to transfer pollutants to the liquid phase and clean the soil. If, in addition to water, other chemical or biological reagents are used in soil washing to increase pollutant dissolution and thus increase removal efficiency, it is called improved soil washing[1]. Meanwhile, surfactants can be used as a washing solution and emulsifier. It should be noted that emulsifiers help to dissolve hydrophobic substances such as petroleum hydrocarbons in water[2].

Gharibzadeh et al reported a 99% performance of Tween 80 surfactant in the soil washing process to remove phenanthrene from soil[3]. In another research, by making an innovative anionic surfactant called AS-5 and using it to clean soil contaminated with petroleum hydrocarbons, a removal efficiency of 52% to 76% has been reported[4]. Another study positively evaluated the use of a combination of Tween 80 surfactant and bentonite in the remediation of soil contaminated with diesel[5].

Considering the above information and the negative economic, social, and environmental effects of soils contaminated with petroleum compounds, the main purpose of this study was to assess the effectiveness of cleaning diesel fuel-contaminated soils using a surfactant-based washing method.

2. Materials and Methods

This research was carried out on a laboratory scale and in a Plexiglas reactor, with a circular cross-section with an inner diameter of 3 cm and a height of 60 cm, the schematic is shown in Figure (1). The contaminated soil was created using a mixture of fine sand, clay, and diesel with different mass ratios. To pump the detergent solution with a specified flow rate to the soil column, peristaltic pumps (model Hei-FLOW Value 01) of Heidolph Company were used.

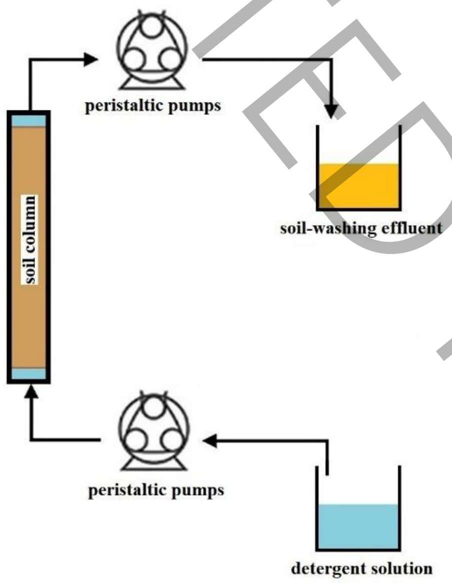

Figure 1. Schematic of the used system

In each experiment, a filter paper was initially placed at the bottom of the column and covered with coarse sand to prevent the exit of fine particles. Then the cylinder was filled with contaminated soil to a height of 50 cm and compacted by the standard Proctor method. Finally, after adjusting the flow rate of the washing solution, the contaminated soil was washed at room temperature (25-28°C) for a specified time with solutions containing different surfactants. The solution was injected into the column using a peristaltic pump. Subsequently, it passed through the soil column, dissolved the pollutant, and discharged as soil-washing effluent from the reactor. In each experiment, the effluent was analyzed at specific time intervals and the system performance was evaluated. The biosurfactant used in this research (rhamnolipid) was obtained from the Iranian Institute of Chemistry and Chemical Engineering. Other chemical surfactants used in this study (SDS and TritonX100) were also obtained from Merck, Germany. The biosurfactant (rhamnolipid) utilized in this study was sourced from the Chemistry and Chemical Engineering Research Center of Iran. Moreover, the chemical surfactants SDS and TritonX100 were obtained from Merck Co., Germany.

3. Results and Discussion

In this section, at first, the effect of changing the mixing ratio of anionic surfactant SDS and nonionic surfactant TX100 in washing water on the cleaning of soil (clay-to-sand ratio of 1 to 9, contaminated with $10\,g\ diesel/kg$) was evaluated in 12 hours. Throughout the experiments conducted in this phase, the surfactant concentration remained constant at $5\,g/L$, the inlet flow rate was 4 ml/min, and the pH of the detergent solution was maintained at 7.8. The results from these experiments indicated that the increase in the non-ionic to anionic surfactant ratio led to improved process efficiency. Therefore, a mixing ratio of 80% TX100 surfactant to 20% SDS by weight was selected for further experiments. In a similar study, to refine soil contaminated with polycyclic aromatic hydrocarbons, the highest removal efficiency of 36% was achieved using the combination of 80% by weight of TX100 surfactant with 20% by weight of SDS surfactant at a concentration of $5\,g/L$ [6].

In the following, the impact of various parameters (the washing solution flow rate, surfactant type, surfactant concentration, pH of the washing solution, washing duration, washing flow direction, soil pollutant concentration, as well as the change of the soil texture) was examined separately using the OFAT method to evaluate system performance. According to the findings (Figure 2), the optimal TPH removal efficiency for each surfactant was achieved after 12 hours of soil washing under an upward flow with a flow rate of $1.5\,mL/min$, pH of 7.8, in soil containing 10% Clay and contaminated with $10\,g\ diesel/kg\ soil$.

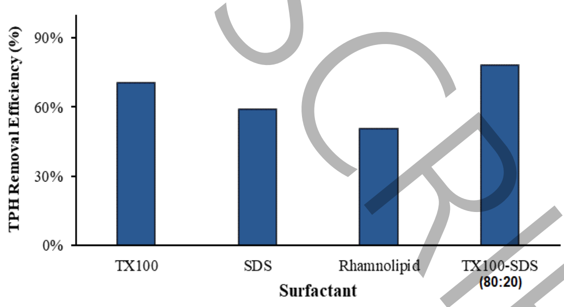

Figure 2. Comparison of TPH removal efficiency from soil by different used surfactants

(pH= 7.8, surfactant= 5 g/L, diesel= 10 g/kg, Q= 1.5 ml/min, t =12 h, clay-to-sand = 1:9)

As can be seen, at the same conditions, among the surfactants used for soil washing, the combined surfactant TX100-SDS has the highest efficiency of 78% in removing diesel from the soil.

Nevertheless, in choosing the most appropriate detergent agent, it is necessary to consider factors such as the characteristics of the polluted environment, the risk to human health and the environment, pollutant characteristics, and costs, in addition to considering the pollutant removal efficiency. According to the mentioned cases, in this research, although rhamnolipid has a lower removal efficiency compared to other surfactants, due to its biodegradability, ability to be used in a wide range of pH and temperatures, and lower toxicity compared to other chemicals surfactants, as a potentially sustainable option, need more investigation and research to achieve effective application and better effectiveness.

4. Conclusion

In the current research, the treatment of soil contaminated with diesel was investigated using the improved soil washing process in a laboratory-scale soil column, by the chemical surfactants SDS and TX100 and the biosurfactant rhamnolipid. Based on the results, with the combination of chemical surfactants TX100 and SDS (mixing ratio of 80:20 %w), during 12 hours of soil washing, under an upward flow rate of $1.5\,\text{mL}/\text{min}$, the pollutant concentration in the soil reduced from $10\,\text{g}/\text{kg}$ to $1.2\,\text{g}/\text{kg}$, which was selected as a suitable washing solution due to its high removal efficiency compared to other used surfactants.

However, considering characteristics like environmental compatibility, low risk, and ease of production of biological surfactants, it is necessary to investigate and test rhamnolipid production and consumption cycle to increase its effectiveness in removing hydrocarbon pollutants from the soil on a larger scale. This study also showed that an improved soil-washing process using surfactants could clean diesel-contaminated soil largely.

5. References

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