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Evaluations of Treatment Performance of Tangerine and Cashew Leaves in TPH Removal from Contaminated Swampy and Clay Soils

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Abstract

This study evaluates the effectiveness of two plant-based treatments, Tangerine (Citrus reticulata) and Cashew (Anacardium occidentale) leaves, in the bioremediation of Total Petroleum Hydrocarbons (TPH) from polluted swampy soil. The performance of these treatments was assessed over an 84-day period using 100g of each treatment. The results demonstrated significant degradation of TPH, with Tangerine leaf showing a slight edge over Cashew leaf in the remediation process of crude oil-contaminated swampy soil. While TPH removal was faster in clay soil during the first six weeks, the performance in swampy soil dominated in the later stages of the study. Both treatments showed comparable effectiveness to other agricultural and organic waste treatments, indicating their potential as sustainable bioremediation agents. The experiment was designed to mimic real-world contamination scenarios, ensuring that the findings could be applicable to large-scale remediation efforts. The degradation rates were monitored at intervals using gas chromatography to quantify the remaining TPH concentrations. The results revealed that while both plant-based amendments facilitated microbial activity, the Tangerine leaf treatment led to slightly higher microbial proliferation, enhancing hydrocarbon breakdown. Cashew leaves, though slightly less effective, still contributed significantly to the remediation process by providing essential nutrients that supported microbial consortia. Soil moisture content and aeration played crucial roles in the degradation dynamics, with swampy conditions promoting a gradual yet sustained breakdown of hydrocarbons. The study highlights the feasibility of utilizing locally available plant materials for environmentally friendly bioremediation. Further research could explore optimization techniques such as combining these treatments with bioaugmentation strategies to accelerate hydrocarbon degradation further.

Keyword: tangerine, cashew leaf, remediation, environmental cleanup, swampy and clay, soils

INTRODUCTION

The contamination of soils with Total Petroleum Hydrocarbons (TPH) is a significant environmental issue, particularly in areas affected by oil spills or industrial activities. [1]. Bioremediation, using plant-based treatments, offers a more sustainable and cost-effective solution. This study focuses on evaluating the potential of Tangerine (Citrus reticulata) and Cashew (Anacardium Occidentale) leaves as bioremediation agents for the removal of TPH from polluted swampy and clay soils [2]. By assessing the effectiveness of these plants at varying treatment weights and over different time intervals, the study aims to determine the most efficient method for TPH removal [3].

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Ex-situ Bioremediation Techniques

These methods involve the excavation of pollutants from contaminated sites, followed by transportation to a different location for treatment. The decision to use ex situ bioremediation techniques is typically based on factors such as treatment cost, pollutant type, pollution severity, soil depth, geographical location, and the geology of the contaminated site. Performance criteria that influence the choice of ex situ bioremediation methods have been discussed [4]

Biopile

Biopile bioremediation involves piling excavated contaminated soil above ground, followed by the addition of nutrients and, at times, aeration, to enhance microbial activity and biodegradation. The core components of this technique include aeration, irrigation, nutrient supplementation, leachate collection systems, and the treatment bed. Biopile technology is increasingly favored due to its cost-effectiveness and its capacity to promote biodegradation, provided that nutrient levels, temperature, and aeration are properly managed [5]

1One of the advantages of biopiles is their ability to limit the volatilization of low molecular weight (LMW) pollutants. This technique is also effective in remediating extreme environments, such as cold regions [6]. For instance, [7] investigated the impact of microbial consortia and mature compost on the reduction of Total Petroleum Hydrocarbons (TPH) in field-scale biopiles under low-temperature conditions. study revealed a 90.7% reduction in TPH in bioaugmented and biostimulated biopile setups, compared to 48% TPH removal in control setups. This substantial reduction was attributed to the synergistic effects of bioaugmentation and biostimulation, showcasing the versatility of biopiles for bioremediation [8,9] .Other studies have demonstrated the feasibility of using biopiles for the bioremediation of various soil types, including clay and sandy soils [9] The adaptability of biopiles allows for shortened remediation times by incorporating heating systems into the biopile design, which increases microbial activity and enhances contaminant availability, thereby accelerating biodegradation [10] Heated air can also be injected into biopiles to simultaneously provide air and heat, facilitating more efficient bioremediation.

Moreover, biopiles are suitable for treating large volumes of contaminated soil within a small footprint. The setup can be easily scaled up to pilot systems to achieve similar performance to laboratory-scale studies [12, 13] [These include the need for robust engineering, high operational and maintenance costs, and challenges such as power supply issues at remote sites, which hinder the uniform distribution of air in the piled soil via air pumps. Additionally, excessive heating may cause soil to dry out, inhibiting microbial activity and promoting volatilization over biodegradation [14].

METHODOLOGY

The study was conducted on polluted swampy and clay soils, where Tangerine (Citrus reticulata) and Cashew (Anacardium Occidentale) leaves were used as treatments for TPH removal. The plants were introduced to the soils at 100g treatment weight, and the degradation of TPH was monitored over 84 days. The percentage of TPH degradation was recorded at various time intervals, with specific focus on the 84th day. Additionally, comparisons of the treatments were made at varying weights (20g to 100g) to assess the influence of treatment quantity on TPH removal efficiency. Performance analysis included comparing the degradation rates of TPH in both soil types, with a particular emphasis on identifying which plant—Tangerine or Cashew leaves—showed superior performance in both swampy and clay soils.

Model Development

Mathematical models were developed to predict the residual TPHs in the respective soils at any given time. In developing the models, the principle of mass balance technique was used to describe the degradation process.

The First Order Biodegradation Rate Kinetic Model

$$\left\{\begin{array}{c}\text{Inflow of}\\\text{mass into}\\\text{system}\end{array}\right\} = \left\{\begin{array}{c}\text{Outflow of}\\\text{mass from}\\\text{system}\end{array}\right\} + \left\{\begin{array}{c}\text{Rate of}\\\text{degradation}\\\text{due to}\\\text{reaction}\end{array}\right\} + \left\{\begin{array}{c}\text{Rate of}\\\text{accumulation}\\\text{of mass}\\\text{within system}\end{array}\right\} \qquad (1)$$

The degradation reaction that takes place in the reactor can be represented by equation (2).

$$TPH \ + \ E \ + \ Z \ \xrightarrow{k_s} \ X \ + \ Z \qquad (2)$$

Where:

$TPH =$ Total hydrocarbon (pollutant) (g)
$E =$ Bacteria
$Z =$ Soil (kg)
$X =$ Biomass (g)
$k_d =$ Degradation rate constant (unit according to model used)

From equation (1) we have

$$\text{Inflow of mass into system } = Q_o C_{TPH(o)} \qquad (3)$$

$$\text{Outflow of mass from system } = QC_{TPH} \qquad (4)$$

$$\text{Rate of TPH degradation } = -r_{TPH}V \qquad (5)$$

$$\text{Rate of accumulation } = -\frac{d(C_{TPH}V)}{dt} \qquad (6)$$

Substituting equation (3) through (6) gives

$$Q_o C_{TPH(o)} = QC_{TPH} - r_{TPH}V + \frac{d(C_{TPH}V)}{dt} \qquad (7)$$

Since there is no flow of materials in a batch reactor, the inflow of mass into reactor is equivalent to the out flow of mass from reactor.

Thus,

$$Q_o C_{TPH(o)} = QC_{TPH} = 0 \qquad (8)$$

Also, for a batch process, volume of reactor (vessel) is constant hence, the accumulation term is

$$\frac{d(C_{TPH}V)}{dt} = V\frac{dC_{TPH}}{dt} \qquad (9)$$

$$-r_{TPH}V = -V\frac{dC_{TPH}}{dt}$$

Or

$$-r_{TPH} = -\frac{dC_{TPH}}{dt} \qquad (10)$$

Assuming that the degradation of TPH is described by first order kinetics, then, we have

$$-r_{TPH} = -\frac{dC_{TPH}}{dt} = k_d C_{TPH} \tag{11}$$

Where:

$Q_o =$ Inlet volumetric flow rate (kg/day)
$Q =$ Outlet volumetric flow rate (kg/day)
$C_{TPH(o)} =$ Initial concentration of Pollutant (TPH) (mg/kg)
$C_{TPH} =$ Instantaneous concentration of Pollutant (TPH) (mg/kg)
$V =$ Volume of reactor (m^3)
$r_{TPH} =$ Rate of TPH degradation (mg/kg.day)

RESULTS AND DISCUSSION

The performances of Tangerine and Cashew leaves in the removal of TPH from polluted swampy and clay soils are evaluated as shown in Figures 1 through 3. While the effectiveness of the treatments in the respective soil was evaluated with respect to time at only 100g weight of treatment.

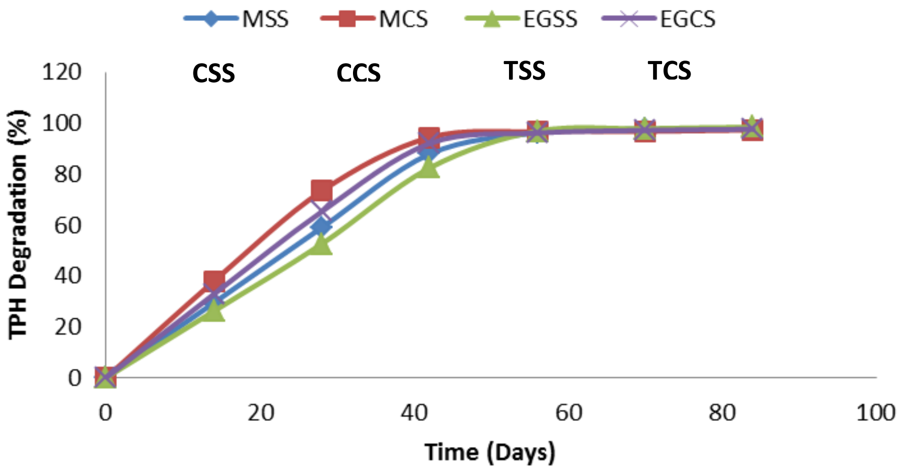

Figure 1. Performance of Tangerine and Cashew Swampy and Clay Soils after 84 Days.

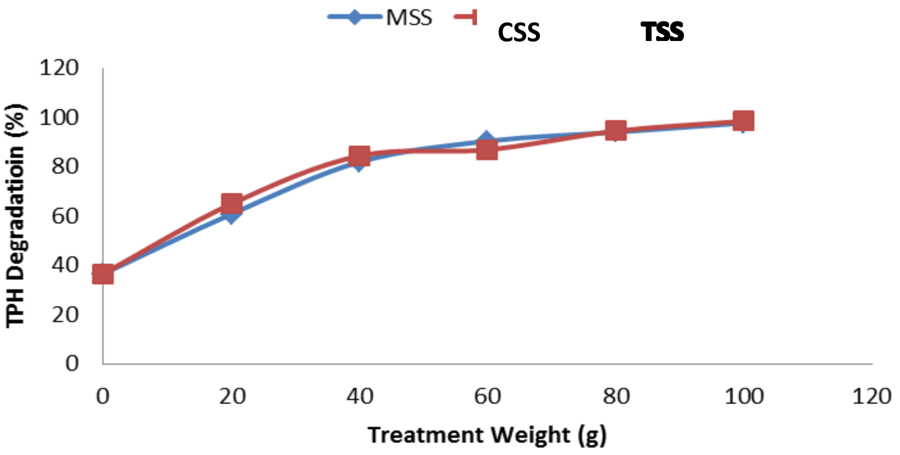

Figure 2. Comparison of TPH Degradation with CSS and TSS.

Figure 1 shows the TPH percentage degradation in swampy and clay soils obtained at

In addition to knowing the performance of Cashew and Tangerine leaves treatments in the respective soils, it is also important to ascertain which of the leaves has better efficiency for TPH removal at the given weights. Thus, Figure 2 shows the TPH degradation percentage at varying treatment weights in swampy soil. This study revealed that TPH degradation percentage increases as treatment weight was increased. However, at the 84th day of the investigation, Tangerine leaf treatment slightly edged the Cashew treatment in swampy soil. However, from the analysis, the TPH degradation percentage in swampy soil at 20g to 100g treatment weight increased from 60.79% to 97.78% with Cashew leaf and 64.95% to 98.50% with Tangerine.

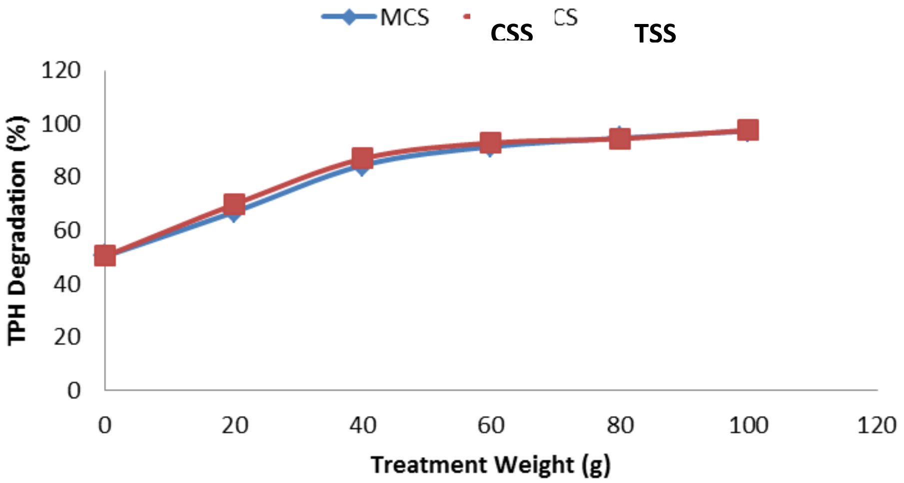

Figure 3. Comparison of TPH Degradation with CCS and TCS.

Figure 3 showed the TPH degradation percentage at varying treatment weights in clay soil. Again, it was revealed that TPH degradation percentage increased as treatment weight was increased in clay soil, while the Tangerine leaf treatment slightly edged the Cashew leaf treatment. The analysis, shows that the TPH degradation percentage in clay soil at 20g to 100g weight of treatment increased from 66.89% to 97.38% with Cashew and 69.74% to 97.69% with Tangerine. This scenario was observed almost in all the treatment options, although, both treatment proved to be effective for bioremediation of Total Petroleum Hydrocarbons content from polluted soil.

RESULTS AND DISCUSSION

The results showed that 97.78% with Cashew and from 64.95% to 98.50% with Tangerine . In clay soil, the degradation increased from 66.89% to 97.38% with Cashew and from 69.74% to 97.69% with Tangerine. In the first 42 days, Cashew in clay soil (CCS) outperformed all other treatments. However, by the end of the study, Tangerine (TSS) slightly edged out Cashew in both swampy and clay soils, although the difference was not statistically significant. The higher nitrogen and phosphorus content in soils treated with Tangerine leaves likely contributed to its superior performance, as these nutrients are essential for supporting hydrocarbon-degrading bacteria. Both treatments showed comparable results to other bioremediation methods using agricultural and organic wastes, such as cassava peels, spent mushroom, and poultry manure.

CONCLUSION

This study demonstrates that both Cashew and Tangerine leaves are effective and comparable bioremediation agents for the removal of TPH from polluted swampy and clay soils. While Tangerine grass showed a slight advantage in degradation rates, both plants proved to be viable options for TPH removal, especially when considering their cost-effectiveness and environmental sustainability. The results highlight the potential of plant-based treatments in addressing petroleum hydrocarbon contamination in soils and suggest further investigation into optimizing these treatments for large-scale applications.

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