

Utilizing Corn Cob for the Bioremediation of Diesel-Contaminated Soil

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Abstract- This research explores the efficacy of corn cob material in remediating diesel-contaminated swampy soil. Biodegradation of diesel hydrocarbons is crucial for restoring soil health, as contamination can impair plant growth and render soil infertile for agricultural and domestic uses. In the study, corn cob was processed by drying it under sun and room temperature, then crushed and sieved into particle sizes ranging from 0.37 mm to 1.86 mm for room-dried (RT) and sun-dried (ST) samples. Different weights of corn cob (25g, 50g, 75g, and 100g) were added to 500g of diesel-polluted soil and assessed over a period of 10 weeks with sampling intervals of 2 weeks. The results showed that room-dried corn cob was more effective in reducing total hydrocarbon concentration (THC) compared to sun-dried corn cob, likely due to nutrient loss in the latter from exposure to sunlight. A reduction of over 80% in THC was achieved with the 100g application of room-dried corn cob. Further analysis using Lineweaver-Burk plots provided insights into the maximum velocity (V_{max}) and Michaelis-Menten constant (K_m) values, which helped in evaluating the bioremediation potential of the material. The findings indicate that corn cob is a promising and effective bioremediant for cleaning up swampy soil contaminated with petroleum hydrocarbons, and its use should be considered in bioremediation strategies for polluted soils.

Indexed Terms- Swampy Soil, Remediation, Corn Cob, Diesel Contaminated Oil, Pollution Control

I. INTRODUCTION

• Background of the Research

The petroleum industry has experienced rapid growth over the past fifty years, with global consumption increasing from 85 million barrels per day in 2006 to a projected 106.6 million barrels per day by 2030. Crude oil, the primary raw material for this industry, is a complex blend of various hydrocarbons [1-2]. Petroleum products are essential for both daily and industrial energy needs. However, leaks and accidental spills during exploration, refining, production, transport, and storage are common [3]. These releases of petroleum hydrocarbons into the environment contribute significantly to soil and water pollution. Contaminated soil poses severe risks to local ecosystems, as the accumulation of pollutants in plants and animals can lead to death or genetic mutations [4-6]. In Nigeria's Niger Delta, oil seepage has been reported between 9 and 13 million barrels across over 2,000 sites. As oil exploration intensified, levels of benzene and polycyclic aromatic hydrocarbons (PAHs) have surged, reaching concentrations 1,800 to 500 times higher than World Health Organization (WHO) standards. Specifically, WHO guidelines set the acceptable limits for PAHs and benzene at 5 $\mu\text{g/L}$ and 10 $\mu\text{g/L}$, respectively [7-10].

• Objectives of the Research

The objectives of this study to assess the effectiveness of corn cobs in remediating petroleum hydrocarbon-contaminated areas are as follows:

- i. To analyze the physicochemical properties of corn cob powder using Gas Chromatography (GC).

- ii. To evaluate the effectiveness of corn cob in bioremediating petroleum hydrocarbon pollution.

II. MATERIALS AND METHODS

Experimental Method

pH Determination

- Reagents and Preparation:

Standard Buffer Solutions: Prepare three standard buffer solutions with pH values of 4.0, 7.0, and 9.2. Dissolve one tablet of each buffer in distilled water to make up a total volume of 100 ml. Fresh solutions should be prepared weekly, as they degrade over time. To prevent mold growth, add three to four drops of toluene to each buffer solution.

- Procedure:

1. Warm-Up: Turn on the pH meter and allow it to warm up for 10 to 15 minutes.
2. Calibration: Standardize the glass electrode with the pH 7.0 buffer solution. After that, calibrate the electrode using either the pH 4.0 or pH 9.2 buffer solutions.
3. Sample Measurement: Place 50 ml of the filtered water sample into a 100 ml beaker. Immerse the glass and calomel electrodes (or a combined electrode) into the sample, ensuring that the lower part of the glass electrode does not touch the beaker's bottom.
4. Recording pH: Switch the pH meter to the pH reading mode. Wait for 30 seconds, then record the pH value to the nearest 0.1 unit. After recording, put the pH meter in standby mode.
5. Electrode Care: After each measurement, remove and gently blot the electrodes dry with filter paper. Store electrodes in distilled water when not in use, and ensure the reference electrode is always in contact with a saturated potassium chloride solution and solid potassium chloride crystals.

Total Hydrocarbon Content (THC) by Gas Chromatography (GC) with Flame Ionization Detection (FID)

- Soil Sample Extraction:

1. Sample Preparation: Add 10 g of soil sample into an amber glass bottle. Add anhydrous sodium sulfate (Na_2SO_4) to remove moisture from the soil, then stir the mixture. Add 300 $\mu\text{g/ml}$ of surrogate standard (1-chlorooctadecane) to the soil.
2. Solvent Addition: Add 30 ml of dichloromethane (DCM) as the extracting solvent. Seal the bottle tightly and place it in a mechanical shaker. Agitate the sample for 5 to 6 hours at room temperature.
3. Filtration and Concentration: Allow the sample to settle for 1 hour after agitation. Filter the mixture through 110 mm filter paper into a clean beaker. Concentrate the filtrate by evaporating it to 1 ml overnight in a fume cupboard.

- Sample Clean-Up:

1. Column Preparation: Prepare a glass column by placing glass cotton at the bottom. Add a silica gel slurry (prepared with DCM) to the column, followed by anhydrous Na_2SO_4 . Add pentane to the column.
2. Sample Transfer and Elution: Mix the concentrated sample extract with cyclohexane in a beaker and transfer it into the prepared column. Elute the sample using pentane, collecting the eluent in a beaker. Further elute with additional pentane and rinse the column with DCM. Allow the eluted sample to evaporate overnight in a fume cupboard.

- Sample Separation and Detection:

1. GC-FID Analysis: Analyze the sample using an Agilent 6890N Gas Chromatograph with a Flame Ionization Detector (GC-FID). Inject 3 μl of the concentrated sample into a GC vial. Clean the syringe by injecting blank DCM three times, then rinse with the sample before injection.
2. Detection: Inject the sample into the GC column for compound separation. The separated compounds pass through the Flame Ionization Detector (FID), which detects them. The total hydrocarbon content (THC) is quantified and reported in mg/kg of soil based on the chromatogram results.

III. RESULTS AND DISCUSSION

Results and Discussion

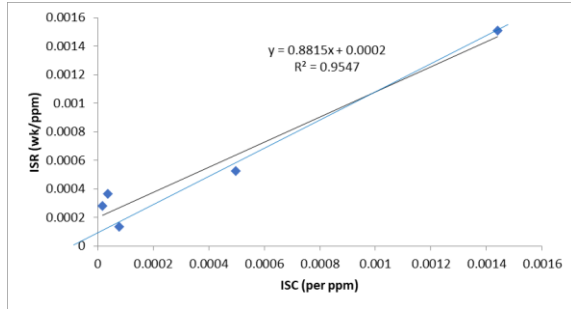


Figure 1: Variation in the Inverse Specific Rate Profile of Bioremediation for Polluted Swampy Soil Using 100g of Room-Temperature Dried Ground Corn Cob, Compared to the Inverse of Substrate Concentration"

Figure 1 shows the Lineweaver-Burk plot based on the Michaelis-Menten model, depicting the experimental values from the bioremediation of polluted swampy soil using 100g of room-temperature dried ground corn cob. The plot displays the inverse specific growth rate on the y-axis against the inverse substrate concentration (ppm) on the x-axis. The blue line represents the Lineweaver-Burk plot, while the black line represents the linear equation fit.

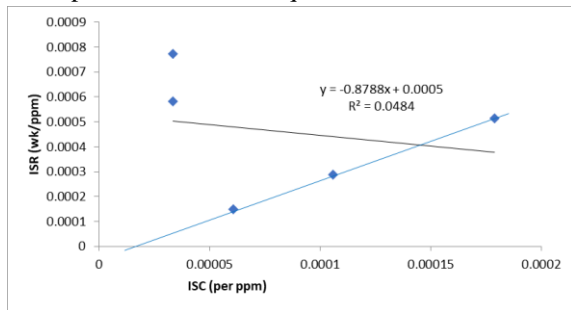


Figure 2: Variation in the Inverse Specific Rate Profile of Bioremediation for Polluted Swampy Soil Using 75g of Room-Temperature Dried Ground Corn Cob, Compared to the Inverse of Substrate Concentration"

"Figure 2 illustrates the relationship between the inverse specific growth rate (wk/ppm) for bioremediated swampy soil, using 75g of room-temperature dried corn cob, and the inverse of the substrate concentration, which represents the hydrocarbon levels in the soil sample under study."

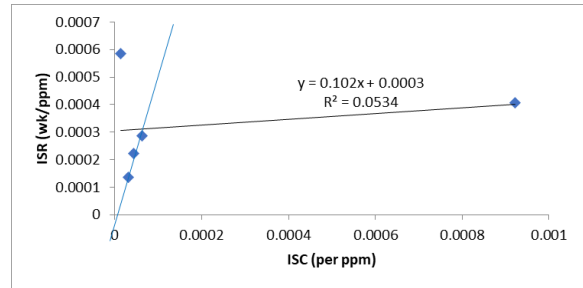


Figure 3: Variation in the Inverse Specific Rate Profile of Bioremediation for Polluted Swampy Soil Using 50g of Room-Temperature Dried Ground Corn Cob, Compared to the Inverse of Substrate Concentration"

Figure 3 illustrates the relationship between the inverse specific growth rate (wk/ppm) for bioremediated swampy soil treated with 50g of room-temperature dried corn cob and the inverse substrate concentration, which reflects the concentration of hydrocarbons in the soil sample. This plot helps determine the ratio of enzyme breakdown and substrate concentration to the formation of the enzyme-substrate complex, which represents the active sites occupied by the enzymes. The plot's intercept is 0.0003, indicating $V_{max} V_{\max} = 3333.3$ ppm/wk, while the slope is 0.102, corresponding to $K_m K_m = 339.9$. This suggests that the substrate concentration is significantly higher than the enzyme's active sites ($K_m K_m \ll [S]$). The R^2 value is 0.0534."

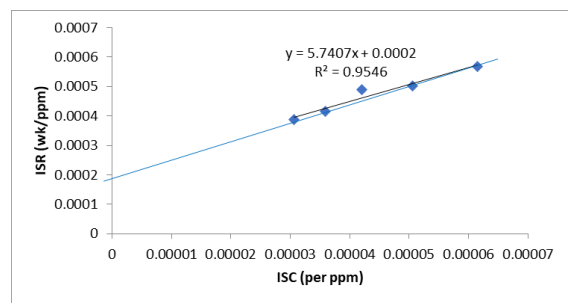


Figure 4: Variation in the Inverse Specific Rate Profile of Bioremediation for Polluted Swampy Soil Using 25g of Room-Temperature Dried Ground Corn Cob, Compared to the Inverse of Substrate Concentration"

"Figure 4 presents the Lineweaver-Burk plot for the catalysis of hydrocarbon contaminants in polluted swampy soil, used to determine the maximum velocity

V_{max} and the Michaelis-Menten constant K_m, which indicate the number of active sites occupied by the enzymes. The bioremediation of the polluted swampy soil was performed using 25g of room-temperature dried ground corn cob. The plot confirms the reliability of the experimental data for the research. The process order is determined to be one (1), as indicated by the line equation. The plot's intercept is 0.0002, yielding V_{max} = 5000 ppm/wk, while the slope is 5.7407, resulting in an K_m value of 28,703.5. The root mean square value is 0.9546, further validating the accuracy and reliability of the experimental results."

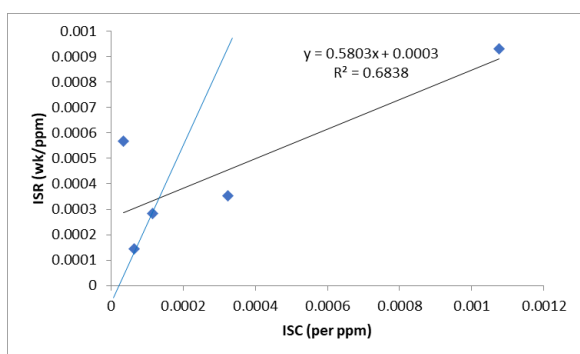


Figure 5: Variation in the Inverse Specific Rate Profile of Bioremediation for Polluted Swampy Soil Using 100g of Sun-Dried Ground Corn Cob, Compared to the Inverse of Substrate Concentration

"Figure 5 shows the relationship between the inverse specific growth rates (wk/ppm) for bioremediated swampy soil treated with 100g of sun-dried corn cob and the inverse concentration of the hydrocarbon contaminant used to pollute the soil. This Lineweaver-Burk plot helps determine the V_{max} and K_m values by analyzing the slope and intercept of the line of best fit derived from the graph."

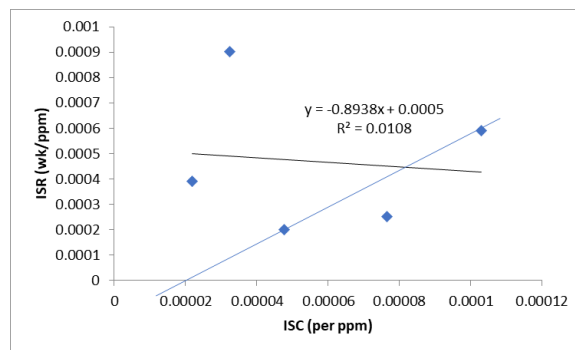


Figure 6: Variation in the Inverse Specific Rate Profile of Bioremediation for Polluted Swampy Soil Using 75g of Sun-Dried Ground Corn Cob, Compared to the Inverse of Substrate Concentration

"Figure 6 illustrates the Lineweaver-Burk plot for the specific microbial growth on polluted swampy soil treated with 75g of sun-dried ground corn cob, in relation to the substrate concentration of the pollutant present in the soil."

CONCLUSION

The research work was aimed at examining the applicability of corn cob on bioremediation of petroleum hydrocarbon on both loamy and swampy soils. The corn cob materials was dried under room and sun temperatures, then crushed and applied on loamy and swampy soil which have been polluted for biodegradation of hydrocarbons spillage in the soil. The petroleum hydrocarbon contain impurities accumulated into the soil for large amount that causes damage and disorder for plants and thus making the soil to be infertile and also leads to land, water and air pollution.

REFERENCES

- [1] Heuze, U., Tran. G., & Lebas, F. (2016). Maize Cobs.Feedipedia, A Programme By INRA, GRAD, HGZ and FAD. <https://www.feedipedia.org/node/718>.
- [2] Ibrahim, M., Riliwan, S., Sirajudeen, A. & Giwa, S. (2016). Remediation of escravous crude oil contaminated soil using activated carbon from coconut shell. *Journal of Bioremediation & Biodegradation*, 7(5)

- [3] Nagarajan, A. & Shanmugam, A. (2016). Mini review of corncob biomass: A potential resource for value-added metabolites. *European Journal of Experimental Biology*, 6(5), 9-13.
- [4] Nigan, P., Armour, G., Banat, I. M., Singh, D. & Marchant, R. (2000). Physical removal of textile dyes from effluents and solid-state fermentation of dye-adsorbed agricultural residues. *Bioresource technology*, 72(3), 219-226.
- [5] Nillanjana, D. & Preethy, C. (2011). Microbial degradation of petroleum hydrocarbon: An overview. *Biotechnology Research International*, (941810)
- [6] Oladele, O. J., Agbabiaka, G. O., Ogungbe, F. & Babarinde, O. (2015). Effect of corn cob particulate on the mechanical and biodegradability properties of reinforced polystyrene composites. *American Journal of Materials Science and Technology*, 4(3), 125-136.
- [7] Oluwaseun, A. (2015). Bioremediation of petroleum hydrocarbon using microbial fuel cells, 4-18
- [8] Omena, B. & Olubukina, O. B. (2017). Microbial and plant-assisted bioremediation of heavy metal polluted environments: A review. *International Journal Environmental Resources*.
- [9] Philip UE, Ibezim EN. Modelling the effect of moringa seed shell on crude oil polluted soils for remediation purposes. *Indian Journal of Engineering*, 2023, 20, e19ije1647 doi: <https://doi.org/10.54905/disssi/v20i53/e19ije1647>
- [10] Ekperi NI, Achinike W. Pectin Extract Optimization from Ripe Cocoa Pod Husks using Response Surface Methodology and Artificial Neural Network. *Indian Journal of Engineering*, 2022, 19(52), 403-409