Bioremediation of Crude Oil-Contaminated Soil Using Poultry Chicken Manure: A Laboratory-Scale Assessment

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Abstract- Crude oil contamination of soil represents a persistent environmental challenge, particularly in oil-producing regions like Nigeria's Niger Delta, where spills degrade ecosystems, agriculture, and public health. This study evaluates the efficacy of poultry chicken manure (PCM) as a cost-effective, eco-friendly bioremediation agent for crude oil-contaminated soil. In a laboratory-scale experiment, contaminated soil samples were amended with PCM at rates of 5%, 10%, and 15% (w/w) and incubated for 3 weeks under controlled conditions. Key parameters monitored included total petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbons (PAHs), microbial populations, and soil physicochemical properties. Results demonstrated significant TPH degradation (75–90%) and PAH reduction (80–95%), with optimal performance at 10% PCM amendment. Microbial counts increased markedly, from 10^4 to 10^7 CFU/g for total heterotrophic bacteria and 10^2 to 10^5 CFU/g for hydrocarbon-utilizing bacteria, correlating with enhanced nutrient availability and pH stabilization. Soil fertility improved, with nutrient (N-P-K) levels rising by up to 400%. These findings underscore PCM's potential as a sustainable alternative to conventional remediation techniques, offering reduced costs (estimated at $10–50 per ton of soil) and minimal environmental disruption. This approach supports greener strategies for restoring contaminated sites in resource-limited settings.

Keywords: Bioremediation, Crude oil contamination, Poultry chicken manure, Total petroleum hydrocarbons, Polycyclic aromatic hydrocarbons, Soil remediation, Microbial degradation

I. INTRODUCTION

Crude oil spills pose severe threats to soil integrity, biodiversity, and human well-being, especially in the Niger Delta, where petroleum exploration has led to widespread contamination. Nigeria, Africa's leading oil producer with over 2 million barrels daily, relies on oil for 35% of its GDP and 90% of export revenue, yet spills from pipelines (50%), sabotage (28%), and operations (21%) have rendered farmlands infertile and polluted water sources (Baird, 2010; UNDP, 2006). Hydrocarbons in crude oil create anaerobic conditions, reduce nutrient availability (e.g., nitrogen, oxygen), and elevate toxic ions like aluminum and manganese, inhibiting plant growth and microbial activity (Ukiwe, L. N., et al. (2017, Lee, K., et al. 2003).

Traditional remediation methods—chemical, physical, and thermal—are often expensive, invasive, and ecologically disruptive. Bioremediation, leveraging indigenous or augmented microbes to degrade pollutants, emerges as a viable, sustainable alternative. Organic amendments like poultry chicken manure (PCM), rich in nutrients (N-P-K) and diverse microbiota, can stimulate hydrocarbon-degrading bacteria (e.g., Pseudomonas, Bacillus) and fungi (e.g., Aspergillus, Penicillium), accelerating breakdown via pathways converting alkanes and aromatics to CO_2 and H_2O (Jain et al., 2011).

This study addresses gaps in PCM's application, including optimal dosing, degradation mechanisms, and interactions with soil microbiota. The aim was to assess PCM's bioremediation efficacy for crude oil-contaminated soil. Specific objectives included: (1) characterizing contaminated soil and PCM; (2) evaluating TPH/PAH degradation and microbial dynamics; and (3) analyzing impacts on soil properties. The scope focused on laboratory experiments with Niger Delta soil, comparing PCM-amended treatments against controls over 3 weeks.

II. LITERATURE REVIEW

Crude oil, a complex mixture of alkanes, cycloalkanes, and aromatics, contaminates soil through spills, affecting physicochemical properties like pH, cation exchange capacity, and redox potential (Fine et al., 1997). In Nigeria, spills have devastated mangroves, fisheries, and agriculture, exacerbating socio-economic woes and health risks such as respiratory and carcinogenic effects (Kadafa, 2012; Inoni et al., 2006).

Bioremediation encompasses bio stimulation (nutrient addition) and bio augmentation (microbe inoculation). PCM, with its high organic matter (moisture 50–70%, N 2–4%, P 1–2%, K 1–3%) and microbial load (10^6–10^8 CFU/g), enhances degradation by supplying carbon, buffering pH, and improving water retention (Adesodun & Mbagwu, 2008). Recent studies report 81–90% TPH reduction with PCM over 20–24 weeks, often augmented by consortia (Akinde et al., 2016; Ojo et al., 2016; Ilori et al., 2019; Oludele et al., 2019). Compared to chemical methods (e.g., dispersants), biological approaches like PCM are 50–70% cheaper and less toxic (Lee et al., 2003).
Gaps persist in short-term efficacy, site-specific adaptations, and scaling to field conditions, which this study addresses.

III. MATERIALS AND METHODS

Study Area and Sample Collection

Contaminated soil was sourced from an oil spill site off NPA Express Road, Effurun-Tori, Warri, Delta State, Nigeria (Lat: 5.677380° N, Long: 5.877886° E). PCM was obtained from Vic-Ben Poultry Farm, No. 9 Odikwe Street, Ekpan, Delta State. Samples were air-dried for 1 week, crushed, and sieved (2 mm mesh) to remove debris.

Experimental Design

In triplicate, 500 g portions of sieved contaminated soil were placed in plastic bowls (A–D). Bowls A–C received 100 g (20% w/w, ~5% effective), 150 g (30% w/w, ~10% effective), and 200 g (40% w/w, ~15% effective) PCM, respectively, and mixed thoroughly. Bowl D served as the unamended control. Moisture was adjusted to 60% with sterile water; setups were aerated thrice weekly via sterile spatulas and incubated at 30 ± 2°C for 3 weeks in a microbiology lab. Baseline and final (week 3) analyses assessed TPH/PAHs, microbes, and soil properties.

Physicochemical and Microbial Analyses

TPH was extracted from 10 g soil using n-hexane/dichloromethane/acetone (1:1:1), sonicated, filtered, and quantified via gas chromatography-flame ionization detector (GC-FID) under standard conditions (injection: 1 μL; column: 30 m × 0.25 mm; temperature: 50–300°C). PAHs were similarly analyzed by GC-MS. Calculations followed:

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\text{TPH (mg/kg)} = \frac{\text{Instrument reading} \times \text{Total extract weight}}{\text{Soil weight}}
$$

IV. RESULTS

TPH and PAH Degradation

Initial TPH averaged 10,000 mg/kg across treatments. After 3 weeks, PCM- amended soils (A–C) showed 75% (Sample A), 85% (B), and 90% (C) reductions, versus 25% in control (D). PAHs declined from 500 mg/kg to 100–120 mg/kg (80–95% efficiency), peaking at 10% PCM.

Treatment
Initial TPH (mg/kg)

Results:

Physicochemical and Microbial Analyses
TPH was extracted from 10 g soil using n-hexane/dichloromethane/acetone (1:1:1), sonicated, filtered, and quantified via gas chromatography-flame ionization detector (GC-FID) under standard conditions (injection: 1 μL; column: 30 m × 0.25 mm; temperature: 50–300°C). PAHs were similarly analyzed by GC-MS. Calculations followed:
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Physical and Chemical Parameters:

Parameter	Initial Value	Final Value	(after 3 weeks) | % Reduction |
TPH (mg/kg)	10,000	2,500	75%
PAHs (mg/kg)	500	100	80%
pH	6.5	7.2	-
Nutrient Content (NPK)	100	500	400%

Microbial enumeration used the pour-plate method: 0.1 mL dilutions on nutrient agar (with 50 μg/mL nystatin for bacteria) and oil agar (Bushnell- Haas medium + 1% sterile engine oil for hydrocarbon utilizers). Plates incubated at 30°C (24 h for total heterotrophs; 5 days for utilizers) and colonies counted (CFU/g). Soil pH, moisture, and N-P-K were measured per standard protocols (e.g., spectrophotometry for nutrients).Total heterotrophic bacteria (THB) rose from 10^4 to 10^7 CFU/g in PCM treatments (1000% increase), while hydrocarbon-utilizing bacteria (HUB) surged from 10^2 to 10^5 CFU/g (500%). Control showed minimal growth.

Microbial Analysis:

Microbial Parameter	Initial Value	Final Value	(after 3 weeks) | % Increase |
Total Microbial Count (CFU/g)	10-4	10-7	1000%
Hydrocarbon- Degrading Microorganisms	10-2	10-5	500%
(CFU/g)			

Data Analysis

Degradation efficiency (%) = [(Initial TPH – Final TPH) / Initial TPH] × 100. Results were statistically evaluated (ANOVA, $p < 0.05$) using available software.

Bioremediation Efficiency:

Treatment | Bioremediation Efficiency (%)	Bioremediation Efficiency (%)
PCM alone | 60%	80%
PCM + Bacterial Inoculants	85%
PCM + Bacterial-Fungal Consortia	90%

V. DISCUSSION

PCM effectively stimulated bioremediation, achieving 75–90% TPH degradation in 3 weeks—faster than reported 20-week trials (81–90%; Akinde et al., 2016; Oludele et al., 2019). Nutrient enrichment and pH neutralization fostered HUB proliferation, aligning with degradation pathways (e.g., alkane oxidation; Nie et al., 2009). The 10% rate optimized efficiency without excess organics risking secondary pollution.

Synergies with indigenous microbes reduced costs versus bioaugmentation ($100,000–300,000/acre) or chemicals ($200,000–500,000/acre), estimating PCM at $101,000–216,000 for 1 acre over 6 months. Limitations include lab-scale focus; field trials are needed for scalability. Compared to phytoremediation ($50,000–150,000/acre), PCM offers broader applicability in nutrient-poor soils (Etim, 2012).

VI. CONCLUSION

Poultry chicken manure proves a potent, affordable bioremediation agent, degrading 75–90% of TPH/PAHs while restoring soil health. This supports sustainable cleanup in spill-prone areas, minimizing ecological harm.

VII. RECOMMENDATIONS

Conduct field-scale trials to validate lab results.

Optimize PCM rates (e.g., 8–12%) via dose-response models. Integrate PCM with bio augmentation for recalcitrant pollutants. Assess long-term effects on groundwater and biodiversity.

Develop policy frameworks for PCM adoption in Nigeria's remediation guidelines.

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