

Evaluation of the Adsorption Capacity and Efficiency of Coir Dust in Crude Oil Spill Remediation

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Abstract- Crude oil remains a cornerstone of modern economies, but its production and handling frequently cause accidental spills that damage ecosystems. Existing remediation techniques, although effective, are often costly or unfriendly to the environment. This study explores the use of coir dust, an agricultural byproduct, as an oil sorbent in a simulated oil-water system. Adsorption capacity and efficiency were evaluated at particle sizes of 0.425mm, 0.600mm, and 1.18mm, with contact times of 20, 40, 60, and 80 minutes. Results showed that smaller particles (0.425 mm) exhibited superior performance, while adsorption increased with longer contact duration, reaching maximum uptake at 80 minutes. These findings suggest that coir dust is an effective, low-cost, and environmentally sustainable adsorbent for managing crude oil spills.

Index Terms- crude oil spill, coir dust, adsorption, particle size, contact time

I. INTRODUCTION

Water is indispensable to human and ecological survival, making its preservation and quality maintenance a global priority. Unfortunately, oil pollution remains a persistent threat due to exploration, production, and transportation activities. Crude oil discharges contaminate surface and groundwaters, with severe impacts on ecosystems, particularly in oil-producing regions such as the Niger Delta. Traditional response methods—including mechanical booms, dispersants, and in-situ burning—are limited by high cost and environmental drawbacks. As a result, adsorption has emerged as an attractive option because it is cost-effective, efficient, and environmentally benign (Syed, 2015). This study examines the suitability of coir dust for oil spill remediation, focusing on the influence of particle size and contact time on adsorption performance.

II. MATERIALS AND METHODS

2.1 Materials Collection and Preparation

Coir dust was sourced locally from coconut husks in Imo State, Nigeria. The fibers were washed to remove impurities, sun-dried, and pulverized to obtain fine dust, which was then stored in a dry environment. Crude oil was collected from Port Harcourt refinery, while water samples were obtained from Otammiri River. Particle size fractions of 0.425 mm, 0.600 mm, and 1.18 mm were obtained using mechanical sieving.

2.2 Experimental Procedure

Experiments were performed in line with ASTM F726-17 guidelines for oil sorbent testing (ASTM International, 2017). The three particle sizes were tested separately. In each trial, 200 ml of river water and 20 ml of crude oil were mixed in a beaker and allowed to stabilize, after which 10 g of coir dust was carefully applied to the surface. Adsorption was monitored at contact times of 20, 40, 60, and 80 minutes. Post-adsorption, the sorbent was separated, oven-dried at 110°C for 30 minutes, and weighed. Oil uptake was determined by the difference between pre- and post-adsorption weights. Each experiment was repeated five times for accuracy. Adsorption capacity and percentage removal were calculated using standard equations as contained in Ismail (2015).

$$\text{Oil adsorption capacity} = \frac{\text{weight of adsorbed oil}}{\text{initial weight of adsorbent}} \quad 2.1$$

$$\text{Percentage of the oil adsorbed} = \frac{\text{weight of the adsorbed oil} \times 100}{\text{weight of the oil introduced}} \quad 2.2$$

2.3 Data Analysis

Mean values of adsorption capacity and efficiency were tabulated, and results were analyzed using analysis of variance (ANOVA) with SPSS software to evaluate the influence of particle size, contact time, and their interaction.

III. RESULTS

Table 1 presents the adsorption capacities of coir dust at different particle sizes and contact times, while Table 2 shows the corresponding percentage oil removal. ANOVA results (Table 3) indicate significant effects of both particle size and contact time on adsorption capacity ($p < 0.05$).

Table 3.1 Adsorption capacity (mg/g) of coir dust at varied particle sizes (in mm) and contact times (in minutes)

CONTACT TIME (MINS)	0.425	0.600	1.180
20	1346	123	1171
40	1463	135	1303
60	1573	143	1371
80	1591	144	1389

Table 3.2 Percentage of crude oil adsorbed by coir dust at different particle sizes and contact times

contact time (mins)	Quantity of Oil used (g)	Weight of coir dust used (g)	Oil adsorbed at 0.425m (%)	Oil adsorbed at 0.600m (%)	Oil adsorbed at 1.18m (%)
20	16.82	10	80.04	73.52	69.62
40	16.82	10	87.00	80.38	77.44
60	16.82	10	93.53	85.01	81.49
80	16.82	10	94.58	85.36	82.56

Table 3.3 ANOVA results for adsorption capacity across particle size and contact time

Tests of Between-Subjects Effects
 Dependent Variable: Adsorption capacity (mg/g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	831836.983 ^a	1	75621.544	316.133	.000
Intercept	115728704.0	1	115728704.0	483798.79	.000
Particle_size	361768.633	2	180884.317	756.179	.000
Contact_time	465510.450	3	155170.150	648.682	.000
Particle_size * Contact_time	4557.900	6	759.650	3.176	.011
Error	11482.000	48	239.208		
Total	116572023.0	60			
Corrected Total	843318.983	59			

IV. DISCUSSION

4.1 Adsorption Tendency of Coir Dust

Coir dust demonstrated strong affinity for crude oil, confirming its potential as a natural sorbent. While effective in oil uptake, its hydrophilic nature means water absorption competes with oil. Previous studies have shown that chemical treatments such as esterification can enhance oleophilicity and reduce water uptake (Asadpour *et al*, 2016).

4.2 Influence of Particle Size

Smaller particle sizes produced higher adsorption values, with the 0.425 mm fraction showing the greatest efficiency. This can be attributed to the increased surface area and reduced pore spacing, which allow for more effective oil entrapment. These results align with findings from other adsorption studies using biomass sorbents (Nwofu *et al*, 2014) and (Idogun, 2016).

4.3 Effect of Contact Time

Adsorption increased with longer contact durations, peaking at 80 minutes, though the improvement from 60 to 80 minutes was marginal, suggesting that the material was approaching saturation. This trend is

consistent with adsorption kinetics reported in prior work like Ikenyiri and Ukpaka (2016).

4.4 Statistical Analysis

ANOVA results revealed significant effects of both particle size and contact time on adsorption capacity, as well as their interaction. These findings confirm that optimizing both parameters is critical to achieving high oil removal efficiency.

V. CONCLUSION

This study demonstrates that coir dust can serve as an efficient, low-cost sorbent for crude oil spill remediation in aquatic environments. Performance was greatest at smaller particle sizes and longer contact times, highlighting the importance of these variables. To further improve oil uptake and reduce water absorption, surface modification of coir dust is recommended. Future work should explore chemical treatments and field-scale validation to enhance its practical applicability.

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