



## Effect of Blended Activated Charcoal–Calcium Carbonate Filler on the Treatment of Abattoir Effluent

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### KEY WORDS

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Activated  
Charcoal  
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Adsorbent

### ABSTRACT

Abattoir effluent is a major source of environmental contamination in developing nations due to its high organic, microbial, and heavy metal load. This study investigates the treatment efficiency of blended activated charcoal–calcium carbonate filler at different ratios (1:1, 2:1, and 1:2). Effluent samples collected from the Warake Road Abattoir in Auchi, Nigeria, were analyzed for physicochemical, nutrient, heavy metal, and microbial parameters following APHA standards. The results showed marked improvements under the 1:2 blend, including BOD and COD reductions of 78% and 80%, TSS and turbidity reductions of 62% and 85%, phosphate reduction to within permissible limits, and >90% microbial reduction. However, residual BOD (68 mg/L), COD (180 mg/L), oil and grease (12 mg/L), and microbial counts still exceeded Nigerian Industrial Standards (NIS), indicating incomplete compliance. Furthermore, iron concentrations increased dramatically from 0.12 mg/L to 1.48 mg/L, nearly five times above the <0.3 mg/L standard, the observed leachate is a result of the coagulant, iron chloride used on the filtrate. While the blended filler demonstrates promise as a low-cost pre-treatment option, its use as a standalone solution is not feasible. Instead, it should be integrated into a multi-barrier treatment system involving biological polishing and final disinfection for full compliance. Future research should prioritize dosage optimization, mitigation of iron leaching, economic evaluation, and management of spent filler materials to ensure long-term sustainability.

### 1. INTRODUCTION

The meat processing industry contributes to food security and the economy but generates large volumes of highly polluted wastewater. Abattoir effluent contains blood, fats, oils, grease, nutrients, pathogens, and trace heavy metals, making it one of the most complex industrial waste streams. When discharged untreated, it leads to oxygen depletion, eutrophication, groundwater contamination, and disease outbreaks (Adeyemo et al., 2016; Ogundipe et al., 2018; WHO, 2022).

In Nigeria and other developing nations, weak regulations and poor infrastructure worsen the challenge, as abattoirs often discharge effluents directly into rivers and streams, exposing communities to health risks (Akinbile et al., 2021; Adeoye et al., 2021). Conventional treatment methods such as sedimentation, coagulation flocculation, and biological processes face limitations with high-strength wastewater, while advanced technologies remain too costly (Ali et al., 2021).

Low-cost adsorbents have emerged as promising alternatives. Activated charcoal, with its high porosity, efficiently removes organics and microbes, while calcium carbonate stabilizes pH and aids coagulation (Ahmed et al., 2020; Adesola et al., 2022). However, little research has examined their combined use for abattoir wastewater in sub-Saharan Africa, particularly regarding compliance with Nigerian Industrial Standards (NIS).

This study evaluates blended activated charcoal–calcium carbonate filler for treating abattoir effluent, focusing on organic load, solids, nutrients, heavy metals, and microbial contamination. It also explores the potential of this low-cost, locally available solution to support sustainable wastewater management and contribute to the United Nations Sustainable Development Goals on clean water and health.

## **2. MATERIALS AND METHODS**

### **2.1 Study Area and Sample Collection**

The wastewater was collected from the Warake Road Abattoir in Auchi, Edo State, Nigeria (Latitude 7.07°N, Longitude 6.27°E). Samples were obtained during peak slaughtering hours (7:00–10:00 a.m.) using sterile 2-liter high-density polyethylene containers, rinsed with nitric acid and distilled water to minimize contamination. Composite samples were pooled from three different days for representativeness, stored in an insulated icebox at 4 °C, and transported to the laboratory within two hours. While this ensured quality preservation, it is noted that pathogen counts could still degrade slightly during transit, which represents a limitation in precise microbial quantification.

### **2.2 Materials**

**Activated Charcoal:** Hardwood biomass was carbonized in a muffle furnace at 600 °C for three hours, ground, and sieved through a 75 µm mesh. This process ensured high surface area for adsorption. However, as later results revealed elevated iron concentrations, future preparation must also consider possible contamination or leaching from equipment.

**Calcium Carbonate:** Natural limestone was washed, pulverized, sieved, and oven-dried at 105 °C. While effective as a buffer, calcium carbonate dissolution during treatment contributed to slight increases in total dissolved solids (TDS), which, although within standards, warrants careful monitoring in sensitive environments.

**Blended Fillers:** Mixtures of activated charcoal and calcium carbonate were prepared in weight ratios of 1:1, 2:1, and 1:2. Only these three ratios were tested, which limits dosage optimization. Finer incremental ratios should be investigated in future research to better understand mechanistic effects and avoid overdosing that could worsen water quality parameters.

### **2.3 Methods**

#### **Sample Preparation**

Raw abattoir effluent was collected from the Warake Road Abattoir, Auchi, Edo State, Nigeria. Each experiment was conducted with 500 mL of effluent placed in 1-liter beakers. The samples were dosed with 20 g/L of the prepared filler blends and agitated on an orbital shaker at 150 rpm for 60 minutes to ensure uniform contact. After agitation, the mixtures were allowed to settle for one hour to facilitate sedimentation. The clarified supernatant was decanted, filtered through Whatman No. 42 filter paper, and preserved for subsequent analysis. All treatments were carried out in triplicate, and average values were reported.

While this ensured reliability, error bars were not incorporated in the data figures, which limited the statistical representation of variability.

**Physicochemical Analysis:** Physicochemical parameters of the effluent were analyzed to assess overall water quality. pH was measured using a calibrated Hanna HI98107 pH meter, turbidity was determined with a HACH 2100Q turbidimeter, and total dissolved solids (TDS) and total suspended solids (TSS) were obtained gravimetrically by filtration and oven drying at 105 °C. A slight increase in TDS was observed in some blends, likely due to partial dissolution of calcium carbonate. Although still within regulatory limits, this suggests the need for long-term monitoring in sensitive environments.

**Oxygen Demand Parameters:** Oxygen demand parameters were analyzed to assess organic pollution levels in the effluent. Dissolved oxygen (DO) was measured using the Winkler titration method, while biochemical oxygen demand (BOD<sub>5</sub>) was determined by incubating samples at 20 °C for five days. Chemical oxygen demand (COD) was analyzed with the closed reflux dichromate method. The 1:2 blend of activated charcoal and calcium carbonate showed the greatest reductions in BOD and COD; however, residual concentrations (BOD = 68 mg/L, COD = 180 mg/L) still exceeded Nigerian Industrial Standards (NIS), indicating incomplete regulatory compliance and the need for supplementary treatment.

**Nutrient Analysis:** Nutrient analysis focused on nitrates and phosphates in the effluent. Nitrate (NO<sub>3</sub><sup>-</sup>) was measured using ultraviolet spectrophotometry at 220 nm after appropriate sample preparation, while phosphate (PO<sub>4</sub><sup>3-</sup>) was determined using the ascorbic acid–molybdenum blue colorimetric method. Results showed that the 1:2 blend achieved the highest phosphate reduction, lowering concentrations to within permissible discharge limits.

**Heavy Metal Analysis** Lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), zinc (Zn), and iron (Fe) were analyzed using Atomic Absorption Spectrophotometry (AAS, PerkinElmer Analyst 400). Calibration was performed with certified standards for accuracy. While most metals remained within permissible limits, iron concentrations increased markedly (up to 1.48 mg/L) after treatment with the 1:2 blend. This fivefold exceedance of the <0.3 mg/L standard is suspected to result from filler leaching or equipment corrosion and represents a major limitation of the study.

**Microbiological Analysis:** Microbiological quality of the effluent was evaluated to determine pathogen reduction. Total coliforms were quantified using the Most Probable Number (MPN) technique, while *Escherichia coli* and *Salmonella* were isolated and enumerated on selective culture media. Yeast and mould counts were obtained through standard plating methods. Although microbial loads were reduced by over 90%, zero-tolerance discharge standards were not met, highlighting the need for additional disinfection within a multi-barrier treatment system.

### 3. RESULTS AND DISCUSSION

#### 3.1 Results

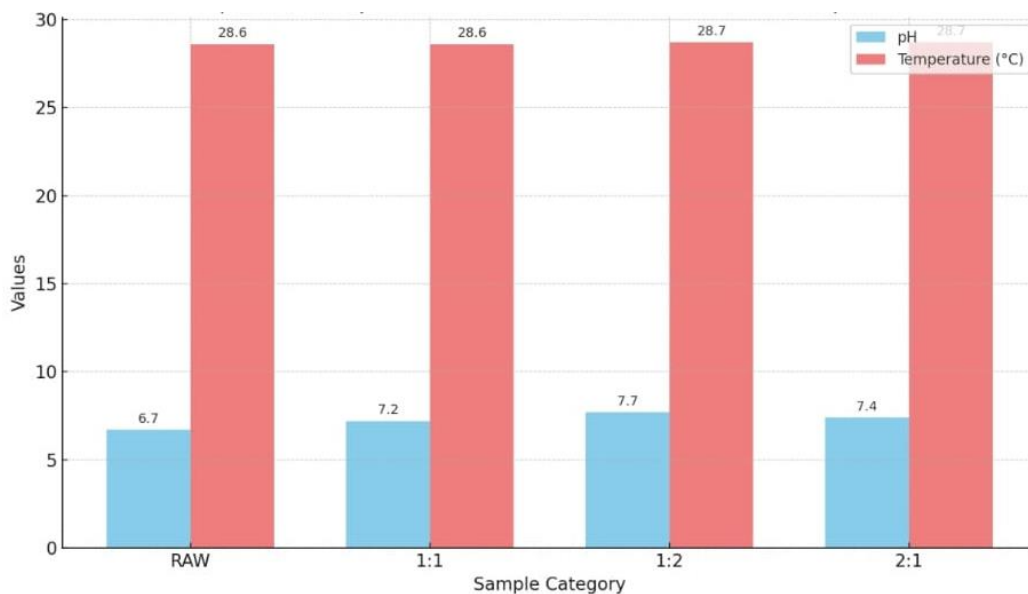
**pH and Temperature:** The pH of the raw effluent was 6.7, slightly acidic but within the permissible discharge range (6.0–9.0). After treatment, pH values improved to 7.2 (1:1), 7.7 (1:2), and 7.4 (2:1). The 1:2 filler ratio produced the most significant neutralization effect due to the buffering role of calcium carbonate, creating a more stable environment for aquatic life and biological processes.

Temperature values across samples remained stable (28.6–28.7 °C), far below the NESREA threshold of 40 °C. This indicates that the treatment process did not add heat stress to the system. Stable thermal conditions are beneficial, as high effluent temperatures can lower dissolved oxygen levels and accelerate odor generation.

**Table 1: pH and Temperature Characteristics**

Sample	Ph	Temperature (°C)
RAW	6.7	28.6
1:1	7.2	28.6
1:2	7.7	28.7
2:1	7.4	28.7

Table 1 and Figure 1 show that the raw effluent had a slightly acidic pH (6.7), which improved after treatment, with the 1:2 blend achieving the best neutralization (7.7). This confirms the buffering role of calcium carbonate. Temperature remained stable (28.6–28.7 °C) across all samples, well below the NESREA limit of 40 °C, indicating no thermal pollution. Overall, the 1:2 ratio provided the most favorable chemical balance for further treatment.

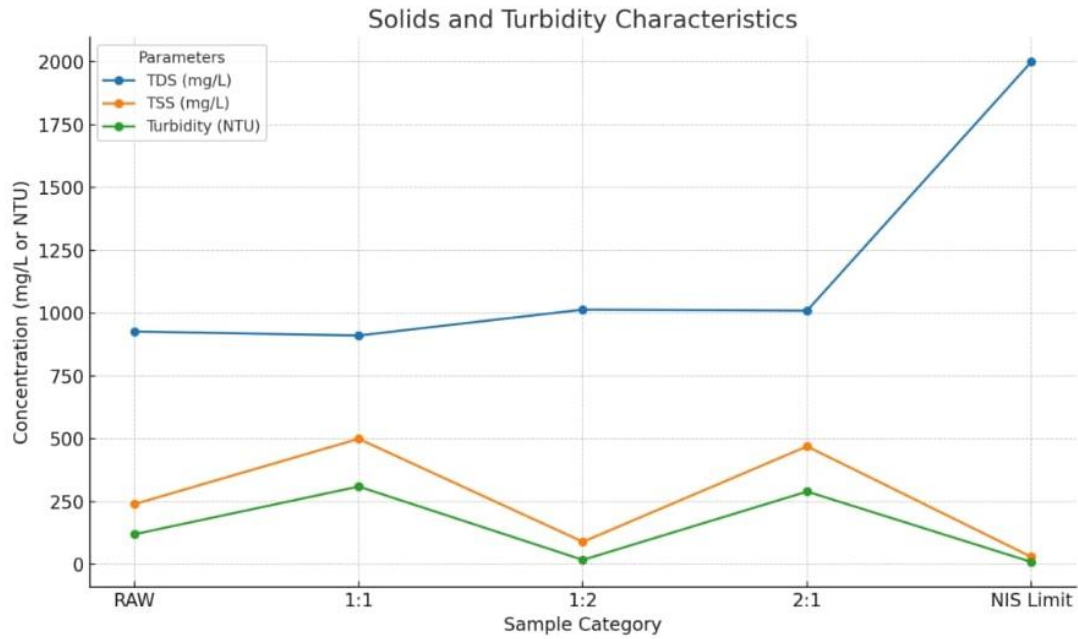
**Figure 1: pH and Temperature Characteristics of Effluent Samples (Bar Chart)**

**Dissolved and Suspended Solids:** The raw effluent recorded TDS of 927 mg/L, within the <2000 mg/L standard. However, TDS increased slightly in the 1:2 and 2:1 treatments due to partial dissolution of calcium carbonate. While this aided pH stabilization, it elevated soluble ions. Although still compliant, the slight increase in TDS raises concerns about potential long-term impacts on sensitive receiving waters, which should be studied further.

**Suspended solids (TSS)** were excessively high in the raw effluent (240 mg/L) compared to the standard (<30 mg/L). The 1:2 treatment effectively reduced TSS to 90 mg/L, while the 1:1 and 2:1 treatments worsened TSS values due to overdosing and poor settling. This suggests dosage sensitivity, likely linked to floc instability or re-release of adsorbed solids, which warrants further mechanistic investigation and optimization of dosage increments. Turbidity followed the same trend. The 1:2 ratio achieved an 85% reduction (120 NTU → 18 NTU), whereas the other ratios increased turbidity.

**Table 2: Solids and Turbidity Characteristics**

Sample	TDS (mg/L)	TSS (mg/L)	Turbidity (NTU)
RAW	927	240	120
1:1	911	500	310
1:2	1014	90	18
2:1	1010	470	290



**Figure 2: Solids and Turbidity Characteristics (Graph)**

Table 2 and Figures 2 show that raw effluent had high TSS (240 mg/L) and turbidity (120 NTU). The 1:2 blend significantly reduced these to 90 mg/L and 18 NTU, though still slightly above limits. In contrast, the 1:1 and 2:1 blends worsened solids and turbidity, indicating overdosing effects. TDS increased slightly in treated samples due to calcium carbonate dissolution but remained within standards. Overall, the 1:2 blend provided the most effective improvement.

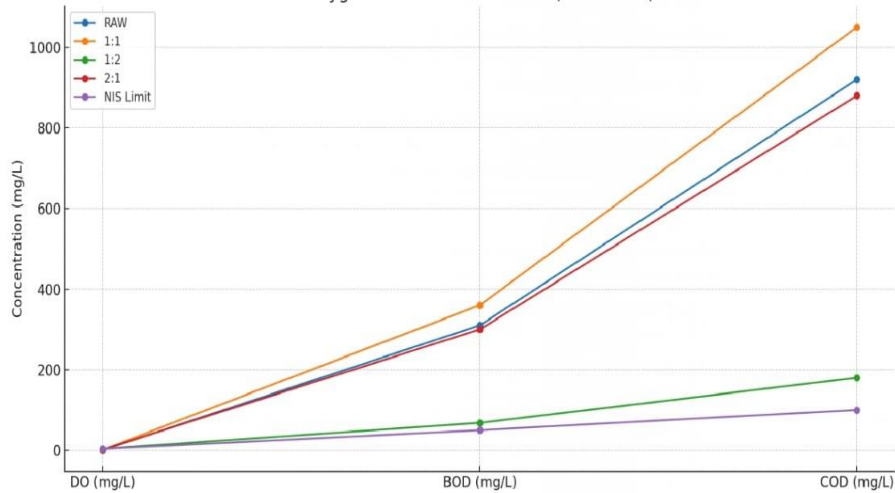
Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD):

The raw effluent showed severe oxygen depletion (DO = 0.8 mg/L) and high BOD (310 mg/L) and COD (920 mg/L), confirming heavy organic pollution.

The 1:2 treatment raised DO to 4.3 mg/L (above the >4 mg/L standard) and reduced BOD and COD by 78% and 80% respectively. However, residual concentrations still exceeded regulatory limits. In contrast, the 1:1 and 2:1 treatments showed poor performance, with the 1:1 COD even exceeding the raw value.

**Table 3: Oxygen Demand Parameters**

Sample	DO (mg/L)	BOD (mg/L)	COD (mg/L)
RAW	0.8	310	920
1:1	1.2	360	1050
1:2	4.3	68	180
2:1	2.0	300	880



**Figure 3: Oxygen Demand Parameters, Line graph**

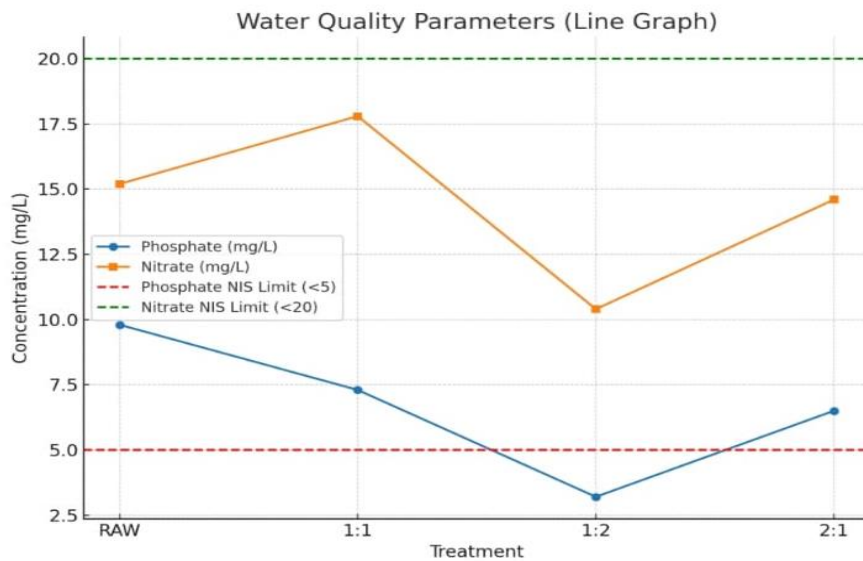
Table 3 and Fig. 3 show the oxygen demand parameters of the raw and treated samples. The raw sample had very low DO (0.8 mg/L) and high BOD (310 mg/L) and COD (920 mg/L), indicating severe organic pollution. The 1:2 mixture was most effective, increasing DO to 4.3 mg/L and reducing BOD and COD to 68 mg/L and 180 mg/L, while the 1:1 and 2:1 ratios showed limited improvement.

**Nutrients (Phosphates and Nitrates)**

Phosphate levels in raw effluent (9.8 mg/L) exceeded the <5 mg/L limit. The 1:2 ratio reduced phosphates to 3.2 mg/L, achieving compliance. Nitrate concentrations were within permissible limits across all treatments, though the 1:2 blend achieved the greatest reduction (15.2 → 10.4 mg/L).

**Table .4: Nutrient Parameters**

Sample	Phosphate (mg/L)	Nitrate (mg/L)
RAW	9.8	15.2
1:1	7.3	17.8
1:2	3.2	10.4
2:1	6.5	14.6



**Figure 6: Water Quality Parameter vs NIS Limits (Graph)**

Table 4 and Fig. 4 present the nutrient parameters of the raw and treated samples. The raw sample showed high phosphate (9.8 mg/L) and nitrate (15.2 mg/L) levels. The 1:2 mixture was most effective, reducing phosphate to 3.2 mg/L and nitrate to 10.4 mg/L, while the 1:1 and 2:1 ratios showed moderate reductions or slight increases in nitrate.

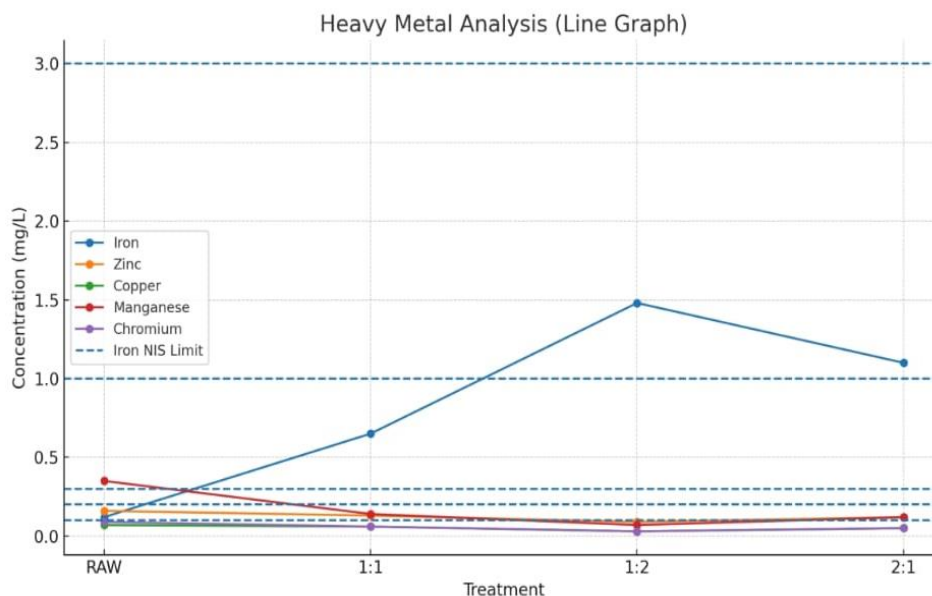
### Heavy Metals

Most metals (Zn, Cu, Mn, Cr) were within permissible limits both before and after treatment. However, iron concentrations rose significantly, from 0.12 mg/L (raw) to 1.48 mg/L (1:2 treatment), nearly five times the <0.3 mg/L standard. This indicates iron leaching, possibly from the filler materials or corrosion of equipment, and represents a serious limitation. Addressing this requires future material optimization and alternative filler pretreatment to minimize contamination.

**Table 5: Heavy Metal Analysis**

Sample	Iron (mg/L)	Zinc (mg/L)	Copper (mg/L)	Manganese (mg/L)	Chromium (mg/L)
RAW	0.12	0.16	0.07	0.35	0.09
1:1	0.65	0.13	0.06	0.14	0.06
1:2	1.48	0.09	0.03	0.07	0.03
2:1	1.10	0.12	0.05	0.12	0.05

Table 5 and Fig. 5 show the heavy metal concentrations in the raw and treated samples. The raw sample had low levels of iron (0.12 mg/L), zinc (0.16 mg/L), copper (0.07 mg/L), manganese (0.35 mg/L), and chromium (0.09 mg/L). The 1:2 mixture was most effective in increasing iron to 1.48 mg/L while reducing zinc, copper, manganese, and chromium to 0.09, 0.03, 0.07, and 0.03 mg/L, respectively. The 1:1 and 2:1 ratios showed moderate improvements, but less effectively than the 1:2 ratio.



**Figure 5: Heavy Metal Analysis (Graph)**

### Oil, Grease, and Microbiological Quality

Oil and grease reduced from 30 mg/L to 12 mg/L under 1:2 treatment, but this remained above the <10 mg/L standard.

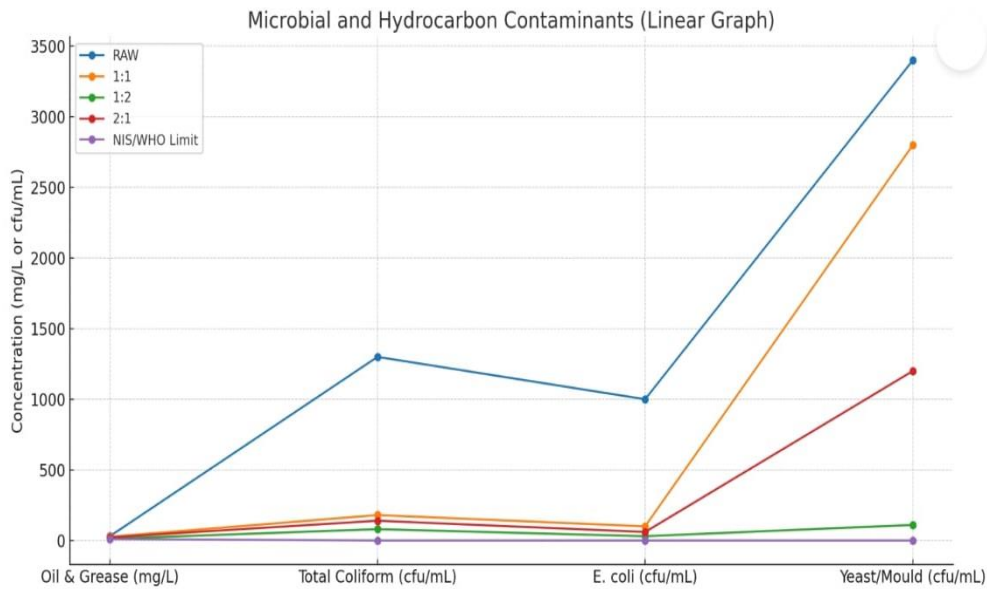
Microbial contaminants were significantly reduced: Salmonella was eliminated, while coliform and E. coli counts decreased by over 90%. Yeast and mold levels also dropped

considerably. Nonetheless, microbial counts did not meet zero-tolerance standards, reinforcing the need for integrating additional disinfection steps within a multi-barrier framework.

**Table 6: Microbial and Hydrocarbon Contaminants**

Sample	Oil & Grease (mg/L)	Total Coliform (cfu/mL)	E. coli (cfu/mL)	Yeast/Mould (cfu/mL)
RAW	30	1300	1000	3400
1:1	26	180	100	2800
1:2	12	80	30	110
2:1	22	140	60	1200

Table 6 and Fig. 6 present the microbial and hydrocarbon contaminants in the raw and treated samples. The raw sample had high levels of oil & grease (30 mg/L), total coliform (1300 cfu/mL), E. coli (1000 cfu/mL), and yeast/mould (3400 cfu/mL), indicating significant contamination. The 1:2 mixture was most effective, reducing these values to 12 mg/L, 80 cfu/mL, 30 cfu/mL, and 110 cfu/mL, respectively, while the 1:1 and 2:1 ratios showed moderate reductions.



**Figures 6: Microbial and Hydrocarbon (Graph)**

### 3.2 Discussion of Findings

The findings demonstrate that treatment performance strongly depends on blend ratios, with the 1:2 ratio consistently outperforming the others across key parameters. While pH, nutrients, turbidity, and microbial loads improved significantly, critical limitations remain. These include: (i) incomplete BOD and COD removal, (ii) significant iron leaching, (iii) oil and grease above permissible levels, and (iv) pathogen counts above zero-tolerance limits.

The poor performance of the 1:1 and 2:1 ratios underscores the importance of dosage sensitivity. Overdosing likely caused floc instability and re-release of pollutants, which should be studied further with finer dosage increments.

The technology also requires a proper economic assessment since claims of low cost were not backed with data. A cost analysis per cubic meter treated and comparison with existing methods would provide decision-makers with better insights. Moreover, the management of spent fillers remains unaddressed, yet critical to the sustainability of the technology.

Finally, while graphical presentations were useful, the absence of error bars limited the statistical robustness of the data. Future studies should incorporate measures of variability to strengthen scientific credibility.

#### 4. Conclusion

Based on the findings of this study, the following conclusions were drawn:

- i. **Treatment Efficiency and Dosage Sensitivity:** The 1:2 activated charcoal–calcium carbonate blend consistently outperformed the 1:1 and 2:1 ratios, significantly improving pH, turbidity, suspended solids, nutrients, and microbial loads. However, dosage sensitivity was evident, as the 1:1 and 2:1 blends worsened key parameters (TSS, turbidity, COD), likely due to overdosing, floc instability, and pollutant re-release, emphasizing the need for finer dosage optimization.
- ii. **Incomplete Regulatory Compliance:** Despite notable reductions in pollutants, residual BOD (68 mg/L), COD (180 mg/L), oil and grease (12 mg/L), and microbial counts exceeded Nigerian Industrial Standards (NIS). This confirms that the blended filler, while effective for pre-treatment, cannot function as a standalone system.
- iii. **Iron Leaching Concern:** Iron levels increased dramatically from 0.12 mg/L in the raw effluent to 1.48 mg/L with the 1:2 blend, nearly five times the <0.3 mg/L permissible limit. This raises critical concerns about filler leaching or equipment corrosion, requiring urgent material optimization to prevent environmental risks.
- iv. **Economic and Sustainability Gaps:** Although the filler is described as low-cost, no quantitative economic analysis (e.g., cost per cubic meter treated, comparison with conventional methods) was provided. Additionally, management of spent filler materials remains unaddressed, posing risks to long-term sustainability and secondary pollution.
- v. **Data Robustness and Engineering Implication:** The absence of error bars and statistical variability in graphical results limited the scientific rigor of the findings. Nonetheless, the blended filler shows strong promise as a low-cost **pre-treatment option** but requires integration into a **multi-barrier treatment system** with biological polishing and disinfection to ensure full compliance with regulatory standards.

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