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Research Article

Performance Evaluation of Blended Activated Charcoal–Calcium Carbonate Adsorbent in the Treatment of Abattoir Wastewater

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Abstract

The discharge of untreated abattoir wastewater poses a significant environmental and public health challenge due to its high concentrations of organic matter, suspended solids, nutrients, and other pollutants. Conventional treatment methods are often expensive and difficult to sustain in developing countries, creating the need for affordable and environmentally friendly alternatives. This study investigated the effectiveness of blended activated charcoal and calcium carbonate (AC–$CaCO_3$) as a low-cost adsorbent for the treatment of abattoir effluent. Wastewater samples were collected from the Warake Road abattoir in Auchi, Edo State, Nigeria, and treated using AC–$CaCO_3$ blends prepared in ratios of 1:1, 1:2 and 2:1. The treatment performance was evaluated by analysing physicochemical parameters, including pH, temperature, total suspended solids (TSS), total dissolved solids (TDS), turbidity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), nitrate, phosphate, and selected heavy metals. The results showed that the adsorption efficiency depended on the blending ratio, with the 1:2 (AC–$CaCO_3$) blend exhibiting the best overall performance. This blend achieved removal efficiencies of 81% for BOD, 83% for COD, 82% for TSS, 72% for nitrate, and 68% for phosphate. Furthermore, the pH of the treated effluent was stabilised within the range of 6.7–7.7, while dissolved oxygen increased significantly from 0.8 to 4.3 mg/L, indicating substantial improvement in water quality. The treated effluent approached the permissible limits specified by the World Health Organization (WHO) and the Nigerian Industrial Standards (NIS) for wastewater discharge. The findings demonstrate that blended AC–$CaCO_3$ is an effective, economical, and environmentally sustainable adsorbent for the treatment of abattoir wastewater and offers a promising solution for improving wastewater management in resource-constrained settings.

Keywords

Abattoir Wastewater, Activated Charcoal, Calcium Carbonate, Adsorption, Effluent Treatment, Water Quality, Sustainable Engineering

1. Introduction

The rapid expansion of livestock processing in developing regions has intensified the release of untreated abattoir effluent into the environment. Abattoir wastewater typically contains blood, fats, soluble proteins, undigested matter, and fecal residues that

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generate excessive organic and nutrient loads [8, 11]. Such effluents exhibit high biochemical oxygen demand (BOD) and chemical oxygen demand (COD), resulting in oxygen depletion and eutrophication when discharged into natural watercourses [1, 12].

In Nigeria, most abattoirs lack adequate wastewater treatment systems. Facilities such as the Warake Road abattoir in Auchi discharge effluents directly into open drains, causing severe contamination of surface and groundwater. This condition leads to ecosystem degradation, biodiversity loss, and public-health risks for surrounding communities [2, 13]. Conventional treatment systems like aeration, coagulation, and biological oxidation are often cost-intensive, complex, and unsustainable for small-scale operations. There is, therefore, a need for locally sourced, low-cost treatment technologies [14].

Adsorption has emerged as a versatile technique capable of removing organic, inorganic, and microbial pollutants through surface interaction between contaminants and adsorbent particles [3]. Locally available materials such as activated charcoal and calcium carbonate are gaining attention for their affordability and environmental compatibility. Activated charcoal, produced from biomass residues, offers high surface area and porosity, while calcium carbonate provides buffering and coagulating effects. Their combination as a blended filler produces synergistic behavior that enhances pollutant removal [4].

Previous studies have confirmed the improved efficiency of hybrid adsorbents through the combined effects of adsorption and precipitation [5, 6, 15]. However, research on AC–$CaCO_3$ blends for abattoir wastewater treatment remains limited, particularly under field conditions typical of Nigerian abattoirs. This study addresses this gap by developing and testing blended AC–$CaCO_3$ fillers and evaluating their treatment performance [10].

Accordingly, the objective is to evaluate the treatment efficiency of blended activated charcoal–calcium carbonate fillers in improving abattoir wastewater quality. The study involves:

1) Collection and characterization of raw wastewater from Warake Road, Auchi;
2) Preparation of AC–$CaCO_3$ blends in ratios 1:1, 1:2, and 2:1;
3) Assessment of pollutant removal performance for major parameters; and
4) Comparison of treated effluent quality with WHO and NIS standards.

2. Materials and Methods

2.1. Study Area

The study was conducted at the Warake Road abattoir, Auchi, Edo State, Nigeria. The abattoir lacks a formal wastewater treatment system and discharges directly into open drains leading to nearby streams.

2.2. Effluent Sampling

Samples were obtained during peak operations (08:00–11:00 am) using sterilized 2-L polyethylene containers prewashed with nitric acid and distilled water. Three samples were composited and preserved at 4°C before analysis, following APHA Standard Methods [7].

Figure 1. *Sample Used.*

2.3. Materials and Reagents

Activated Charcoal (AC): Prepared from hardwood sawdust carbonized at 600°C for 2 h and sieved to 150 µm.

Calcium Carbonate ($CaCO_3$): Derived from natural limestone, washed, oven-dried at 105°C, and sieved to 150 µm.

Analytical Reagents: Potassium dichromate, ferrous ammonium sulfate, and concentrated sulfuric acid.

Equipment: pH meter (Hanna HI2211), UV–Vis spectrophotometer (Hach DR 3900), and Atomic Absorption Spectrophotometer (PerkinElmer AAnalyst 400).

2.4. Preparation of Blended Fillers

Three blends were prepared by weight: Sample A (1:1), Sample B (1:2), and Sample C (2:1). Each mixture was homogenized using a mechanical stirrer and stored in airtight containers.

2.5. Treatment Procedure

For each test, 200 mL of effluent was treated with 5 g of blended filler in a 500 mL beaker. The mixture was stirred at 200 rpm for 30 min, allowed to settle for 24 h, and filtered. Control (untreated) samples were analyzed concurrently.

Figure 2. Blended Activated Charcoal–Calcium Carbonate.

2.6. Analytical Methods

Table 1. Analytical Methods.

Parameter	Method	Reference
pH, Temperature	Electrometric	APHA (2017)
TSS, TDS	Gravimetric	APHA (2017)
BOD	Winkler method	APHA (2017)
COD	Dichromate oxidation	APHA (2017)
Nitrates/Phosphates	Spectrophotometric	APHA (2017)
Heavy Metals	AAS	ISO 8288 (1986)

2.7. Data Analysis

All experiments were conducted in triplicate. Removal efficiency was computed as:

$$\frac{C_i - C_f}{C_i}\, x\, 100 \qquad (1)$$

where C_i and C_f are the initial and final concentrations, respectively. Significance was evaluated at $p < 0.05$ using ANOVA.

3. Results and Discussion

3.1. Physicochemical Characterization of Raw Effluent

The untreated effluent exhibited a dark red-brown color, strong odor, and high turbidity due to suspended organic matter and fats. Table 2 summarizes the raw effluent characteristics, confirming severe contamination and the need for effective treatment.

Table 2. Physicochemical Characteristics of Raw Abattoir Effluent.

Parameter	Observed Value	WHO/NIS Limit	Remarks
pH	6.7	6.0–9.0	Slightly acidic
Temperature (°C)	28	< 30	Within range
BOD (mg/L)	360	< 30	Excessively high
COD (mg/L)	1050	< 250	Excessive organic load
TSS (mg/L)	500	< 30	Poor clarity
TDS (mg/L)	650	< 500	High dissolved solids
Nitrate (mg/L)	24	< 10	Above limit
Phosphate (mg/L)	19	< 5	Above limit
DO (mg/L)	0.8	> 4.0	Oxygen deficient

These results align with earlier studies reporting high organic and nutrient pollution in abattoir effluents [1, 2].

3.2. Effect of Treatment on Oxygen Demand

The 1:2 AC–CaCO3 blend achieved the highest reduction in BOD and COD. This improvement is attributed to the combined adsorption of organic matter by activated charcoal and oxidation catalysis promoted by calcium carbonate.

Table 3. Oxygen Demand Parameters Before and After Treatment.

Parameter	Raw	1:1	1:2	2:1	WHO Limit
BOD (mg/L)	360	310	68	300	<30
COD (mg/L)	1050	920	180	880	<250
DO (mg/L)	0.8	1.2	4.3	2.0	>4.0

The 1:2 blend reduced BOD and COD by 81% and 83%, respectively, and increased DO by over 400%.

3.3. Removal of Suspended and Dissolved Solids

The 1:2 ratio produced an 82% TSS reduction and 70% TDS reduction, enhancing clarity and reducing turbidity. The synergistic effect between adsorption and precipitation explains the improved removal efficiency.

Table 4. Removal Efficiency for Suspended Solids and Dissolved Substances.

Parameter	Raw (mg/L)	Treated (1:2) (mg/L)	Removal Efficiency (%)
TSS	500	90	82
TDS	650	195	70
Turbidity (NTU)	118	20	83

3.4. Nutrients and Heavy Metal Removal

Nitrate and phosphate concentrations dropped by 72% and 68%, respectively, due to adsorption and ionic interaction with calcium ions. Heavy metals exhibited strong affinity to the carbon surface, with lead showing the highest removal (79%).

Table 5. Nutrient and Heavy Metal Removal Efficiencies for 1:2 Blend.

Parameter	Raw (mg/L)	Treated (mg/L)	Removal Efficiency (%)
Nitrate (NO_3^-)	24	6.7	72
Phosphate (PO_4^{3-})	19	6.1	68
Lead (Pb)	0.33	0.07	79
Zinc (Zn)	0.42	0.13	70
Copper (Cu)	0.31	0.08	73
Chromium (Cr)	0.27	0.10	63
Cadmium (Cd)	0.15	0.05	65

The improved performance demonstrates the ability of the blended filler to simultaneously reduce nutrient enrichment and metal toxicity.

3.5. Microbial Reduction

The total coliform count decreased from 1.2×10^3 to 1.8×10^2 CFU/mL, corresponding to 85% removal. The alkaline buffering of CaCO3 and adsorptive surfaces of activated charcoal reduced microbial load, improving effluent hygiene [9].

3.6. Overall Performance Evaluation

The 1:2 AC–CaCO3 blend consistently produced the highest pollutant reduction across all tested parameters.

Table 6. *Summary of Optimum Treatment Performance.*

Parameter	Removal Efficiency (%)
BOD	81
COD	83
TSS	82
TDS	70
Nitrate	72
Phosphate	68
Pb	79
Cu	73
Zn	70
Cd	65
Cr	63
Coliforms	85

This confirms that the 1:2 ratio ensures an ideal balance between adsorptive surface area and buffering capacity.

4. Conclusion and Engineering Implications

The blended activated charcoal–calcium carbonate adsorbent demonstrated strong potential for abattoir wastewater treatment. The 1:2 ratio achieved optimal removal efficiency for organic matter, solids, nutrients, and metals, bringing effluent quality close to WHO and NIS discharge limits. The method is low-cost, eco-friendly, and suitable for small-scale abattoirs.

Engineering implications include modular deployment of AC–$CaCO_3$ filters in decentralized wastewater systems, minimal operation cost, and potential integration into sustainable abattoir infrastructure.

Abbreviations

BOD Biochemical Oxygen Demand
COD Chemical Oxygen Demand

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Author Contributions

Eshiole Lucky Oshiobugie: Data curation, Methodology
Ibrahim Abdulrazaq Olayinka: Validation
Wasiu John: Supervision
Sule Joseph: Visualization

Conflicts of Interest

The authors declare no conflict of interest.

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