Research Article

Assessment of Biochar Corn (*Zea mays*) Cob and Coconut Guinit as Media for Treating Public Market Wastewater

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Abstract
Public market discharges often enter surface waters untreated, carrying extremely high organic loads and dissolved/suspended solids. Locally abundant agricultural residues, corncob and coconut guinit, offer a potentially low-cost filtration medium, yet remain understudied in market waste applications. This study evaluated a gravity-fed vertical filtration prototype using three corncob biochar masses (≈247, 389, 530 g; corresponding layer thicknesses ~5, 7.5, 10 cm) sandwiched between constant coconut guinit layers downstream of a pebble pre-filter. Raw public market wastewater from Isabela City, Basilan, was passed through each configuration. Effluents were analyzed for Biological Oxygen Demand (BOD), Total Dissolved Solids (TDS), turbidity, and color. The results were compared with the Philippine DENR DAO 2016-08 Class C effluent standards. Maximum mean reductions were 25.7% (to 2,760 mg/L) for BOD, 29.0% TDS (to 5,072 mg/L), 5.3% turbidity (to 60.1 NTU), and 16.0% color (to 17,707 CU). None met regulatory limits (BOD <50 mg/K; TDS <1,000 mg/L; turbidity <5 NTU). One-way ANOVA revealed no statistically significant differences among biochar dosages ($p > 0.05$). Findings show that inactivated corncob biochar plus guinit media provide only modest polishing of very high-strength market wastewater under short, uncontrolled contact times. Performance might improve through media activation, optimized particle grading, controlled HRT, and integration with biological or chemical pre-treatment. The work establishes baseline data for further development of low-cost, community-scale treatment options using locally available wastes.

Keywords: *biochar, corncob, coconut guinit, wastewater treatment, low-cost filtration*

Introduction

Public markets are vital food distribution points across the Philippines, but they are also significant sources of high-strength wastewater, which contains high concentrations of biodegradable organics, suspended solids, fats, oils, and dissolved substances (Zulkifli et al., 2011). Due to insufficient on-site treatment, these pollutants often enter drainage systems and nearby surface waters, exacerbating environmental issues such as oxygen depletion, eutrophication, and increased public health risks downstream (Khatri & Tyagi, 2014). In many low-resource settings, conventional wastewater treatment plants are either economically or logistically unfeasible, creating a pressing need for affordable and decentralized treatment technologies. Agricultural by-products, particularly biochar produced from crop residues, offer a promising solution due to their low-cost nature and significant filtration properties. Biochar, produced through the pyrolysis of organic matter, possesses a high internal surface area, micro- and mesoporosity, and functional groups that enable the adsorption of organic matter, nutrients, and metals (Xiao et al., 2020). Corncob, a commonly available lignocellulosic waste material, can be pyrolyzed to produce biochar with substantial sorptive potential, making it an ideal candidate for wastewater treatment (Ali et al., 2016). Similarly, coconut guinit, the fibrous layer between the husk and the shell, is a coarse, resilient matrix that effectively traps particulates and supports microbial attachment, enhancing its utility in filtration systems (Balamurugan et al., 2019). Both corncob and coconut guinit are abundant in Mindanao and are often underutilized, presenting a valuable opportunity for circular economy applications when diverted from agricultural waste streams.

Despite the established benefits of various biochars such as rice husk, bamboo, and wood, as well as coconut coir in wastewater treatment (Gunasekaran et al., 2020), the combined use of corncob biochar and unmodified coconut guinit in gravity-fed filtration systems for treating high-strength public market wastewater has not been well-documented, particularly within the Philippine context. There is a significant gap in data regarding the removal efficiencies of these materials for key wastewater pollutants, including biochemical oxygen demand (BOD), total dissolved solids (TDS), turbidity, and color, particularly under field-relevant conditions. This study aims to address this gap by evaluating the performance of a vertical filtration prototype incorporating three different dosages of corncob biochar, layered with constant coconut guinit thicknesses, to treat raw public market wastewater. The specific objectives are to quantify the changes in BOD, TDS, turbidity, and color across low, medium, and high biochar loadings, test for statistically significant differences in removal performance among treatments, and compare the treated effluents with the Philippine Department of Environment and Natural Resources (DENR) DAO 2016-08 Class C regulatory threshold.

Material and Methods

Research Design

The research employed a quasi-experimental design with a pre-test and post-test approach, using a control group and three experimental groups to assess the effectiveness of corncob biochar combined with coconut guinit in treating public market wastewater.

Wastewater Collection

Wastewater was collected from the meat section of the public market in Isabela City, Basilan (southern Philippines), a high organic loading source (Ghani 2011). Composite grab sampling from multiple vendors yielded ~50 L of raw wastewater per experiment batch. Samples were transported in clean containers to the researcher’s processing site, handling minimized extraneous contamination.

Filter Media Sourcing and Preparation

The filter media for the study were sourced and prepared as follows: approximately 25 kg of air-dried corncobs, sourced from local farmers in Barangay Maasin, Zamboanga City, were used as the corncob feedstock. The corncobs were washed and air-dried for 48 hours before being pyrolyzed in a batch drum kiln. A 50-liter charge of corncob was nested inverted in a 200-liter steel drum packed with fuel wood and dry biomass. The drum lid was fitted with a 3-inch GI pipe vent, and the pyrolysis process was conducted at an approximate peak temperature of 500°C for 2 hours. After cooling for 5-6 hours, the biochar was recovered, washed to remove fines, and drained. For coconut guinit, the fibrous layers from about 50 coconuts sourced from Lamitan City were manually separated, cut to fit the filter boxes, and rinsed. The thickness of the guinit was standardized to approximately 2.5 cm per layer to cover the planned area of the filtration container. Lastly, the pebble pre-filter consisted of river pebbles, which were washed to remove silt and oils, with a bed thickness of approximately 5 cm.

Filtration Prototype Configuration

The filtration prototype was configured with a three-tier wooden frame (approximately 160 cm in height, 60 cm in width, and 40 cm in depth), which supported stacked plastic filter boxes. The first component, the influent reservoir, featured a perforated base made of 0.5-inch PVC pipe, equipped with a ball valve for coarse flow control. The second component, the pre-filter box, contained 5-mm perforations and was filled with 5 cm of washed pebbles to remove gross solids. The third component, the media box, also had 5-mm perforations and contained a sandwich assembly: 2.5 cm of coconut guinit at the top, a variable thickness layer of corncob biochar in the center, and 2.5 cm of coconut guinit at the bottom. Finally, the effluent catchment, an unperforated container, was placed to collect the filtrate for sampling.

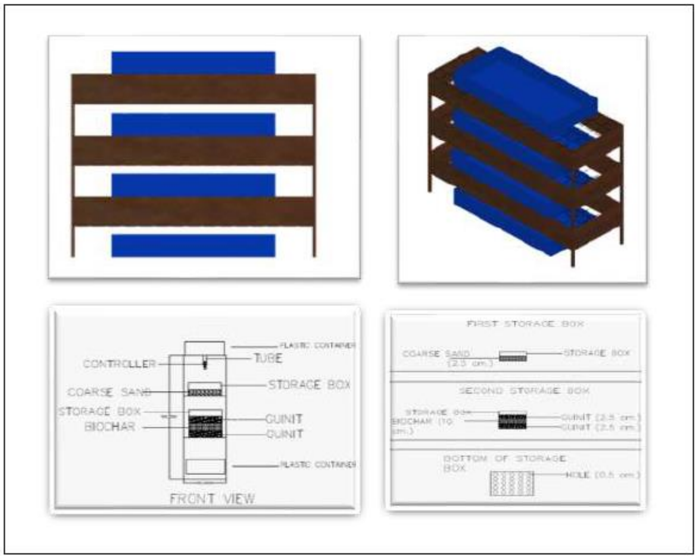

Figure 1. Vertical Filtration Design

Treatment Configurations

Biochar core depth and mass were varied across three treatments while coconut guinit is constant. Each treatment processed 15 L of wastewater per run under gravity flow. Actual flow rates and HRT were not instrumented; visual valve regulation sought comparable throughput across replicates

Table 1. Experimental treatment of the study

Treatment	Biochar Mass (g)	Biochar Thickness (cm)	Coconut Guinit (cm, top & bottom)	Replicates
T1	247	5	2.5 each	3
T2	389	7.5	2.5 each	3
T3	530	10	2.5 each	3
Control	0	0	0	1 (raw wastewater baseline)

T1 - Treatment 1, T2 - Treatment 2, T3 - Treatment 3

Sample Handling and Laboratory Analyses

Effluents were collected immediately after filtration, stored in clean containers at 4°C, and then delivered to the DOST Region IX laboratory for analysis. Standard methods were employed for the analysis of various parameters, including BOD5, which was measured using the incubation (dilution) method (Triola, 2018; Zar, 2010). Total dissolved solids (TDS) were determined gravimetrically by drying the samples at 180°C. Turbidity was measured using the nephelometric method with a unit of Nephelometric Turbidity Unit (NTU), and color was assessed through visual comparison, with results reported in color units (CU/TCU). All raw influent and treatment effluents were analyzed in triplicate where applicable.

Statistical Analysis

For each response variable (BOD, TDS, turbidity, and color), treatment means and percentage reductions relative to raw wastewater were calculated. The normality of the data distribution was assessed using the Shapiro-Wilk test, and one-way ANOVA was used to test for differences among the means of treatments T1, T2, and T3 ($\alpha = 0.05$). The data were presented in tables and figures.

Result and Discussion

Table 2 presents the results from the experimental study on the use of corncob biochar coconut guinit as a filtration medium for public market wastewater treatment in terms of color, Turbidity, TDS, and BOD.

Table 2. Mean influent and effluent quality; percentage reduction by treatment

Parameter	Raw	T1	Reduction (%)	T2	Reduction (%)	T3	Reduction (%)
Color (CU)	21,080	17,706.7	16.0	19,493.3	7.5	20,533.3	2.6
Turbidity (NTU)	63.5	61.87	2.6	60.13	5.3	63.57	0
TDS (mg/L)	7,148	6,095	14.7	5,072.3	29.0	6,712	6.1
BOD (mg/L)	3,712	2,943.7	20.7	2,759.7	25.7	3,004.7	19.1

TDS – Total Dissolved Solids, BOD – Biological Oxygen Demand, T1 - Treatment 1, T2 - Treatment 2, T3 - Treatment 3

The results show that the color had the highest variability, as reflected in the raw wastewater, which exhibited a high color intensity of 21,080 CU, indicative of substantial organic and inorganic contaminants. Treatment 1 achieved the highest color reduction at 16.00%, lowering the color to 17,706.67 CU. This suggests that a lower dosage of biochar may facilitate better flow of wastewater, enhancing the adsorption of color-causing compounds. Treatment 2 and treatment 3 showed lesser reductions of 7.53% and 2.59% respectively, possibly due to media compaction or saturation at higher biochar dosages. This finding is consistent with Azabache-Liza et al. (2022), 42 who demonstrated the efficacy of coconut-endocarp-based biofilters in reducing color in runoff water by up to 86% due to their porous structure and surface chemistry.

For Turbidity, the initial turbidity of the wastewater was 63.5 NTU. Treatment 2 demonstrated the most significant turbidity reduction at 5.31%, bringing the value down to 60.13 NTU. Treatment 1 achieved a 2.56%, while Treatment 3 showed a slight increase in turbidity with -0.11%, possibly due to the release of fine particles from over-saturated media or clogging. These modest results indicate that while coconut guinit and biochar have a filtration effect, they may need refinement for significant turbidity removal. Prior studies by Azabache-Liza et al. (2022) reported turbidity removal efficiencies of up to 87.5% using coconut-based activated carbon filters under optimized conditions.

For Total Dissolved Solids (TDS), the raw wastewater had a TDS concentration of 7,148 mg/L. Treatment 2 achieved the highest TDS reduction at 29.06% reducing the concentration to 5,072.33 mg/L. Treatment 1 and Treatment 3 showed reductions of 14.73% and 6.11%, respectively. Biochar's performance here can be attributed to its well-known ion exchange and adsorption capabilities due to high surface area and functional group on its surface, which bind with soluble salts and inorganic matter. Ghizlane et al. (2020) affirm that biochar produced from agricultural wastes can efficiently adsorb various ions and compounds responsible for high TDS levels.

For BOD, the level in the raw wastewater was 3,712 mg/L. Treatment 2 showed the highest reduction at 25.66%, lowering BOD to 2,759.67 mg/L. Treatment 1 and treatment 3 achieved reductions of 20.69% and 19.08% respectively. BOD reduction reflects the removal of biodegradable organic matter from the water, which biochar is capable of adsorbing through physical and chemical mechanisms. However, despite the observed reductions, none of the treatments achieved compliance with the effluent limits set by DENR DAO 2016-08 for Class C water, which indicates that additional design or media modifications may be required to improved treatment efficiency.

Although uncertain improvements were observed in the pollutant concentration after treatment, the reductions were not sufficient to meet the regulatory thresholds set by DAO 2016-08. The highest BOD reduction was recorded at 25.66% using medium biochar dosage, and the highest TDS reduction at 29.03% - both still failed to achieved the acceptable limit for Class C water of DENR DAO 2016-08. To understand the performance outcomes, it is important to compare both the filtration design and biochar dosages used in this study with the published studies.

This study utilized biochar dosages of 247 g, 389 g, and 530 g, treating 15 liters of wastewater per treatment run. This corresponds to approximate dosage concentrations of 49.4 g/L, 77.8 g/L, and 106 g/L, respectively – substantially higher than those commonly reported in the literature. For instance, Thongkrua and Suriya (2022) achieved over 80% COD and color removal using only 20 g/L of activated corncob biochar in a continuous-flow system. Likewise, Chen et al. (2022) used 30 g/L of ultrasound and acidmodified corncob biochar and reported over 93% of COD and ammonium removal in a constructed rapid infiltration system.

Despite applying significantly larger quantities of raw biochar in the present study, pollutant reduction remained modest – only 25.66% for BOD and 29.03% for TDS at best. This suggests that biochar dosage alone is not the primary determinant of filtration efficiency. Instead, factors such as media activation, flow regulations, contact time, and surface chemistry are like more influential. For example, Zhao et al. (2020) demonstrated a >90% of Pb2+ removal using just 10 g/L of $CuFe2O$4-modified corncob biochar due to improved surface area and reactive sites.

Thus, while the current study tested relatively high biochar doses, the absence of media activation and unregulated hydraulic retention likely contributed to the lower removal performance.

The analysis of BOD among the three treatment groups revealed no statistically significant difference, as indicated by a p-value 0.8362 (Figure 2), which exceeds the conventional threshold of 0.05. This suggests that the varying dosages of corncob biochar in combination with a constant coconut guinit layer did not produce a substantial effect on the BOD levels of the treated public market wastewater. Although the mean BOD values range from 2759.67 mg/L to 3004.67, the differences were not large enough to indicate a meaningful variance in organic pollutant removal.

This may imply that while the biochar treatments have some capacity to adsorb biodegradable organic matter, the observed dosages and biochar-guinit ratios used in the setup may not be an optimal configuration for BOD reduction. Furthermore, insufficient contact time or the biochar's limited surface activation for adsorbing biodegradable organics may also contribute to the result.

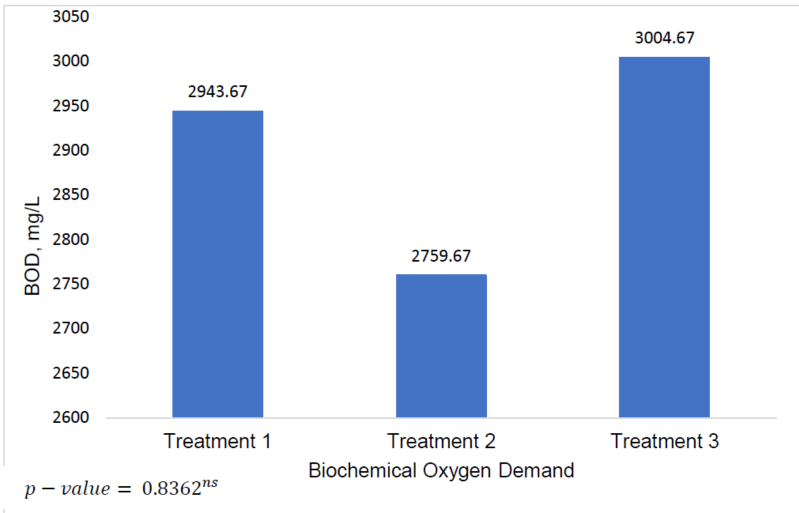

Figure 2. Analysis of Variance Result on Biological Oxygen Demand. ^{ns} *– no significant difference*

For Total Dissolved Solids (Figure 3), the experimental group result showed no statistically significant difference, with a p-value of 0.2930. This indicates that, despite observable variations in group mean values, there is a notable difference in the mean, with 5072.33 mg/L in Treatment 2 compared to the high of 6711.67 mg/L in Treatment 3. Although treatment 2 appeared to lower TDS more effectively, the variability between groups was not statistically significant.

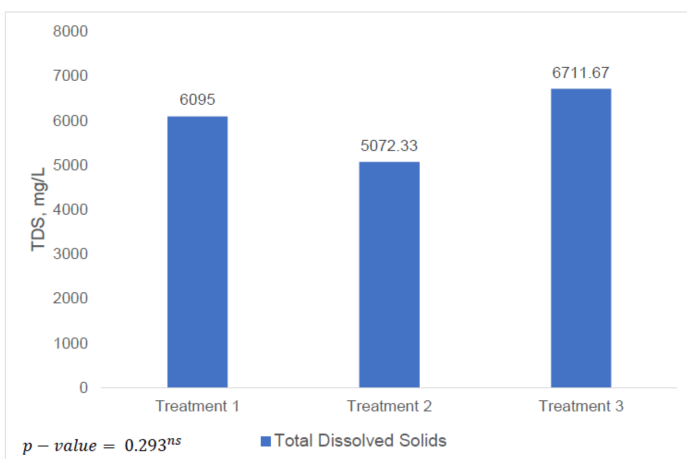

Figure 3. Analysis of Variance Result on Total Dissolved Solid.
^{ns} *– no significant difference*

This outcome suggests that the dosages of biochar applied did not yield a meaningful impact on dissolved ion concentration in the wastewater. However, the numerical difference between treatments suggests that treatment 2 could be a more promising configuration for future optimization, possibly due to improved exchange kinetics or balanced media permeability at intermedia dosage.

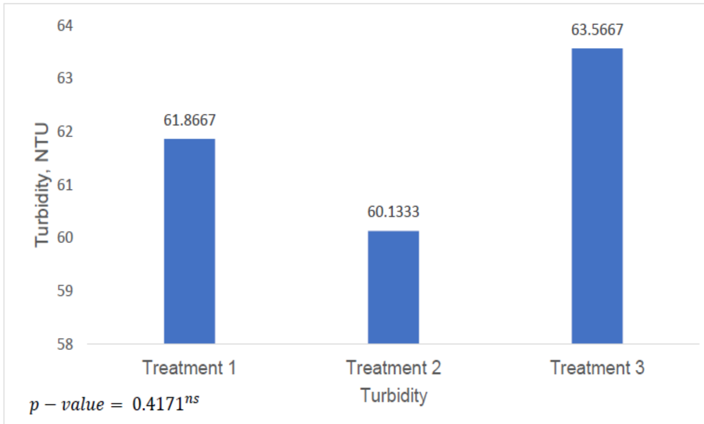

Figure 4: *Analysis of Variance Result on Turbidity.*
^{ns} – no significant difference

The turbidity analysis (Figure 4) also did not exhibit a statistically significant difference across the three treatments, with a p-value of 0.4171. The group means remained relatively close – from 60.13 NTU to 63.57 NTU. This suggests that the corncob biochar and coconut guinit combination offered a comparable level of particulate reduction across all treatment experiments. The modest reduction in turbidity could be attributed to the physical straining capability of the filter media, particularly the fibrous structure of guinit and the porous structure of biochar. However, the lack of statistical significance indicates that the effectiveness of these materials in trapping turbid-causing particles was consistent regardless of the biochar dosage. This implies that turbidity removal reached a saturation threshold, where increasing the biochar content no longer yields additional benefit under the same flow conditions. The filtration mechanism for turbidity could be enhanced by introducing a multi-layered bed with graded particles or by extending the filtration duration to allow more efficient particle capture and settling.

The DENR DAO 2016-08 sets the effluent standards to regulate pollutant levels in wastewater before discharge. This table will evaluate the effectiveness of corncob biochar and coconut guinit as filter media in reducing BOD, TDS, turbidity, and color in public market wastewater. The results are compared against the DAO 2016-08 class C for effluent standards to assess compliance and treatment efficiency.

Table 3: Comparison of Raw and Treated Wastewater to DENR DAO 2016-08 for Class C Water

Parameter	DENR DAO 2016-08 Limit for Class C	Baseline for Percent Reduction	Treatment 1	Treatment 2	Treatment 3
Color (CU)	150 CU	21,080	17,706.67	19,493.33	20,533.33
Turbidity (NTU)	< 5 NTU	63.5	61.8667	60.13	63.567
TDS (mg/L)	< 1,000 mg/L	7,148	6,095	5,072.33	6,712
BOD (mg/L)	< 50 mg/L	3,712	2,943.67	2,759.67	3,004.67

The table 3 presents the comparison of raw and experimented wastewater samples to the effluent standards set by DENR DAO 2016-08 for Class C water. The color values across all treatments- ranging 17,706.67 to 20,533.33 CU – remained high compared to typical internation references values, and no Philippine standard currently defines an acceptable limit for color under DAO 2016-08. For turbidity levels, all samples also exceeded the maximum allowable limit of < 5 NTU, with values ranging 60.13 to 63.57 NTU, indicating inadequate removal of suspended particles. Similarly, TDS values – despite being reduced from the raw water level of 7,148 mg/L – remained above the 1000 mg/L standard across all treatments, with the lowest recorded value of 5,072.33 mg/L. For BOD, the level was significantly high in the raw sample (3,712 mg/L) and remained far beyond the allowable limit of < 50 mg/L in all treatments, with the lowest BOD concentration observed at 2,759.67 mg/L. Overall, none of the treatments met the DENR DAO 2016-08 compliance thresholds for the tested parameters, highlighting the need for enhanced or supplementary treatment processes, such as incorporating finer filtration media, extending contact time, implementing multi-stage treatment systems, or integrating chemical or biological treatment methods to improve pollutant removal efficiency.

Conclusion

The use of corncob biochar and coconut guinit as filtration media showed some potential in reducing key wastewater pollutants, such as BOD, TDS, turbidity, and color. However, the overall treatment efficiency did not meet the regulatory standards set by DENR DAO 2016-08 for Class C waters. Despite applying relatively high biochar dosages, the modest reductions observed suggest that factors beyond biochar quantity, such as media activation, flow regulation, and contact time, play a more significant role in optimizing filtration performance. It is recommended that future research focus on optimizing the filtration design by adjusting media activation, controlling hydraulic retention time, and exploring the potential of hybrid filtration systems. Additionally, further studies should assess the long-term performance, reusability, and scalability of biochar and coconut guinit in wastewater treatment applications, particularly in decentralized settings like public markets, to enhance their feasibility as a cost-effective and sustainable alternative to conventional treatment methods.

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