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Treatment of Slaughterhouse Wastewater Using Coco Fibers as Media in the Fixed Bed Biofilm Reactor

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***Abstract*— *Slaughterhouse wastewater is a significant environmental challenge due to its high levels of organic matter, fats, oils, and grease (FOG), as well as suspended solids. Conventional treatment methods, while effective, are often expensive and resource-intensive, making them less accessible for small-scale operations in developing regions like Zamboanga City, Philippines. The potential of coconut fiber as a cheap and environmentally friendly filter media for the treatment of slaughterhouse wastewater in a Fixed Bed Biofilm Reactor (FBBR) is examined in this study. A lab-scale FBBR system was designed and tested over six trials to evaluate its efficiency in reducing key pollutants, including Biochemical Oxygen Demand (BOD5), Total Suspended Solids (TSS), and FOG. The coco fiber media achieved a lower mean effluent BOD_5 concentration (350.17 mg/L) compared to the control media (573.50 mg/L). The paired t-test for BOD_5 removal resulted in a t-value of 2.8276 and a p-value of 0.3039, indicating no significant difference between the two media. The Shapiro-Wilk test for TSS yielded a W-statistic of 0.7161 and a p-value of 0.001209, indicating a significant deviation from normality. The Mann-Whitney U test for TSS removal resulted in a p-value of 0.47152, suggesting no statistically significant difference between coco fiber and Kaldnes K1. The Shapiro-Wilk test for O&G removal resulted in a W-statistic of 0.9213 and a p-value of 0.2972, confirming non-normality. The Mann-Whitney U test for O&G removal showed a p-value of 0.57548, indicating no significant difference between the two media. The findings highlight the potential of coconut fiber as an eco-friendly and cost-effective alternative to synthetic media in wastewater treatment. However, further optimization of operational parameters and the inclusion of a tertiary treatment process are recommended to improve compliance with effluent standards.*

***Keywords*— *Slaughterhouse wastewater, Coco fiber, Fixed bed biofilm reactor (FBBR), Wastewater treatment, Biofilm technology, Organic waste remediation, Natural filter media, Bioreactor performance, Industrial effluent, Sustainable treatment methods*.**

I. INTRODUCTION

The meat processing sector accounts for 29% of the total freshwater utilized by the agricultural industry (Mekonnen & Hoekstra, 2019). Moreover, worldwide production of beef, pork, and poultry has doubled over the last decade and is expected to continue rising until 2050. This trend has led to an increase in the number of slaughterhouses facilities, which in turn is anticipated to generate a higher volume of slaughterhouse wastewater (SWW) that requires treatment (Bustillo-Lecompte et al. 2019) identified slaughterhouse wastewater as one of the most detrimental types of wastewater for the environment, categorizing it as agricultural and food industry waste. Conventional treatment methods, including dissolved air flotation (DAF), anaerobic and aerobic treatment, and the FBR Process, are expensive and necessitate substantial infrastructure. Recently, alternative approaches like biofilm reactors have been developed to provide more efficient and cost-effective treatment solutions. FBBRs, represent a sophisticated technology designed to effectively treat wastewaters with high to extremely high levels of organic contamination (SAMCO Technologies, 2023).

In the Philippines, merely 10% of wastewater undergoes treatment, and 58% of groundwater is polluted. Projections indicate that by 2025, water availability will be limited in most major cities and in 8 out of the 19 principal river basins nationwide. Waterborne illnesses continue to pose a serious public health threat, with approximately 4,200 fatalities each year attributed to contaminated drinking water. In Sta. Cruz, Laguna, a project backed by LISCOP involves the establishment and operation of a Decentralized Wastewater System (DEWATS), which processes wastewater from the town's slaughterhouse before it is released into the river. Regulations related to wastewater management in the country are frequently poorly enforced, resulting in environmental ramifications (Claudio, 2020).

Slaughterhouse wastewater treatment typically employs conventional methods such as Dissolved Air Flotation (DAF), anaerobic and aerobic systems, and constructed wetlands, each with its own strengths and limitations. DAF, for instance, effectively removes suspended solids and oil but can be costly and energy-intensive, while anaerobic systems offer reduced operational costs but struggle with long retention times and odor control. Especially in settings with high organic loads like slaughterhouses, The Fixed Bed Biofilm Reactor (FBBR), which enhances microbial activity through biofilm growth on media, has shown promise in treating high BOD5 wastewaters. FBBRs typically use media such as foam or ceramic, but innovations in media selection could improve both performance and sustainability (SAMCO Technologies, 2023).

Current research on FBBR in slaughterhouse wastewater treatment has primarily focused on synthetic or industrial media, which can be costly and not always sustainable (Vidal et al., 2019). With this, this study aimed to investigate the feasibility and effectiveness of utilizing coco fibers as filter media in a Fixed Bed Biofilm Reactor (FBBR) for treating wastewater from slaughterhouses. Despite the availability of studies exploring various media options, there is limited research on the use of natural materials, particularly in the

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local context, and cost-effective alternatives. This study addresses this gap by investigating the use of coconut fiber, a locally abundant and environmentally friendly material, as a filter media in FBBRs.

II. METHODOLOGY

A. Systematic Experimental Set-up Design

The experimental setup, based on the design by Thomas and Knepper (2022), features a 10-liter reactor tank fitted with 1.27 cm diameter flexible hoses wrapped in coconut fibers to support biofilm growth. An aeration system with a 60 L/min air blower and air stones ensures proper oxygen distribution. The reactor includes an inlet and outlet to control wastewater flow. Weekly 30-minute backwashing was implemented to clear debris and maintain media performance, preventing clogging and ensuring efficient treatment.

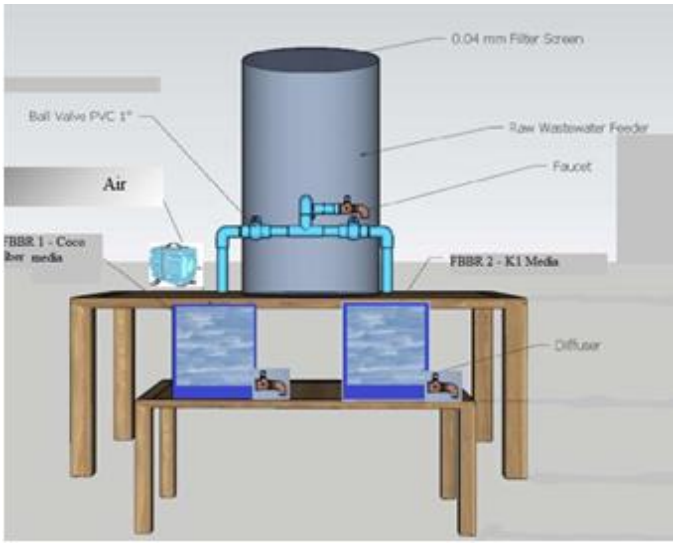

FIGURE 1. The actual Systematic Experimental Setup Design used during the experiment

B. Filtering Media Specifications

The media setup used 1.27 cm diameter hoses filled and wrapped with tightly wound coco fibers to support biofilm growth and water filtration. Mesh screens secured the fibers, and the hoses were vertically arranged in a crate submerged in the reactor tank for even wastewater flow. A 60 L/min air blower ensured proper aeration. The porous, biodegradable coco fibers provided a sustainable and efficient alternative to synthetic media, supporting the study's goal of eco-friendly wastewater treatment.

C. Preparation of Materials

The preparation of materials for the FBBR involved a selection of equipment and supplies essential for effective wastewater treatment using coco fiber. The materials are listed in Table 1, which outlines their quantities, types, and specific purposes within the study.

In the preparation phase, the 1.27 cm diameter, 33 cm long flexible hoses were used to construct the coco poles, which serve as the media for the FBBR. The filter screens, with pore sizes of 0.04 mm and 0.1 mm, were employed for wastewater screening and media support, respectively. The 20-liter containers will be used to collect the effluent, while the PE drum, with a 200-liter capacity, serves as the storage tank for wastewater. The glass tank, measuring 17 x 17 x 37 centimeters with a 10-liter capacity, functioned as the treatment tank where the main biological processes occur. A flexible hose, with a diameter of 1.27 centimeters, facilitated the distribution of wastewater throughout the reactor. An air blower equipped with a controller and a 60L/min air pump, both crucial for maintaining proper aeration, used to support microbial activity within the tank. Horizontal air stones were strategically placed to ensure even distribution of oxygen, enhancing reactor efficiency.

TABLE 1. Materials used during the experiment

Quantity	Materials	Purpose
20pcs 1.27 cm diam. flexible hose	Flexible hose and coco fiber	Used as primary media
2 meters	Filter Screen (0.04mm)	Used for wastewater screening
1 meter	Filter Screen (0.1mm)	Used for media support
20 pcs	20L Container	Used to collect effluent
2 pcs	10L Aquarium 17x17x37cm	Used for treatment tank
1 pc	PE Drum (Capacity: 200L)	Wastewater storage tank
2 pc	PVC Pipe (d=25.4mm)	Used for wastewater distribution
1 pc	60L/min Air pump	Used for aeration in the tank

D. Flexible Hose and Coco fibers Preparation

Flexible hoses were bought from a local hardware store and cut into 33 pieces of 30cm length. Only high-quality coco fibers were chosen for this purpose.

E. Initial Cleaning and Pre-Treatment of Coco fibers

Before assembly, the coco poles were soaked in a tub of clean water overnight. This procedure aids in the removal of any residual dust, debris, or organic material that may be trapped inside the fibers. Soaking allows the fibers to expand and absorb water, simulating their behavior during wastewater treatment.

F. Assembly of the Flexible Hose Media

Thirty flexible hoses (1.27 cm diameter, 33 cm length) were prepared as filter media by filling them with compressed coco fibers and sealing both ends with 0.1-mm mesh to prevent fiber escape. Additional coco fiber was spirally wrapped around each hose to increase biofilm surface area. The ends were further secured with 0.04-mm mesh screens. Each assembled coco pole underwent a mechanical agitation test to ensure stability under flow conditions in the reactor.

G. Preparation of 200-L Drum

A 200-liter HDPE drum was used as a storage tank for managing influent and effluent in the FBBR system. It was equipped with two 30-mm PVC pipes—one for raw wastewater intake and the other for treated water discharge—each sealed to prevent leaks. Gate valves on both lines allowed

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for precise flow control, while a removable lid minimized contamination and eased maintenance and sampling.

H. Setting up the Air Pump

One unit air pump was used in this study. The pump serves as the aeration apparatus in the tank. Also, fish tank oxygen hoses were used as air passages and air stones were placed at the end so that equal amounts of air were distributed in the tank.

I. Waste Management Procedures

The wastewater management procedures involved transferring raw wastewater into the FBBR tank through the influent line, with flow controlled by a gate valve to ensure consistent input. Treated water exited via the effluent line into an aquarium tank, with both flow rates regularly monitored and adjusted for optimal reactor performance. Routine inspections were conducted to check for leaks and blockages in the system, ensuring uninterrupted operation. Six sets of influent and effluent samples were collected throughout the experiment and sent to a laboratory for analysis of parameters such as BOD_5, TSS, O&G, pH, and temperature. All procedures were conducted using proper safety measures, including the use of PPE and regular sanitization of the work area to maintain hygiene and prevent contamination.

III. Result and Discussion

Biofilms were observed on the surface of the coco fiber media. These biofilms appeared as thin and slimy layers which indicates successful colonization by microorganisms. The structure and texture of the coco fiber media provided an adequate surface area for biofilm attachment and growth which supports the biological treatment process. The formation of biofilms highlights the effectiveness of the coco fiber as a medium for pollutant degradation and consistent with the expected performance of media in an FBBR system. This observation aligns with findings from previous studies where biofilm growth was noted as a critical factor in the efficiency of alternative biocarriers. Figure 2 shows the photo of coco fiber media after the experiment.

FIGURE 2. Coco Fiber Media After the Experiment

In the FBBR system using Kaldnes K1 as the control media, visible biofilms were also observed after the experiment. The Kaldnes K1's optimum design for microbial attachment is demonstrated by the way the biofilms are somehow dispersed throughout the surface of the media. These biofilms contributed to the effective reduction of BOD5, TSS and O&G confirming the high efficiency of the commercial media in facilitating biological treatment. The presence of biofilms on both the coco fiber and control media underscores the suitability of both materials for use in FBBR systems. Figure 3 shows the photo of the control media after the experiment.

FIGURE 3. Control Media After the Experiment

The characteristics of raw wastewater in the slaughterhouse were highly contaminated with influent BOD_5 levels ranging from 945 mg/L to 4,260 mg/L, far exceeding the DAO 2016-08 Class C standard of 50 mg/L. TSS levels from 46 mg/L to 370 mg/L and O&G, ranging from 74 mg/L to 249 mg/L, far exceeding the regulatory standard of 5 mg/L. all of the Parameters did not meet the Class C effluent standards specified under DAO 2016-08. The FBBR using coco fibers attached inside of a flexible hose demonstrated promising efficiency in treating slaughterhouse wastewater. Removal efficiencies reached as high as 98.89% for BOD5, 91.42% for TSS and 92% for O&G across the trials. These results indicate that Coco fibers can effectively function as bio carriers providing an adequate surface area for biofilm growth and pollutant degradation. The Kaldnes K1 media which was used as the control also showed high efficiency in removing BOD_5 up to 97.25% and O & G at 89.18% but exhibited variability in TSS removal with several trials resulting in negative removal efficiencies due to operational turbulence. Despite these inconsistencies, the control media maintained overall strong performance. Comparative analysis revealed that coco fiber media FBBR performed better than the control media (Kaldness K1) particularly in BOD5 and TSS removal. Statistical tests confirmed a significant difference in performance. The paired t-test for BOD_5 removal resulted in a t-value of 2.8276 and a p-value of 0.3039, indicating that there was no statistically significant difference between the two media at the 95% confidence level. The Mann-Whitney U test for TSS and O & G removal yielded a p-value of 0.57548, and a p-value of 0.47152 for O & G. The findings validate the potential of coco fibers as a cost-effective and sustainable alternative to conventional media like Kaldnes K1. The treated wastewater of both coco fiber media and Kaldnes K1 media did not consistently meet the Class C effluent standards specified under DAO 2016-08 for BOD_5 (50 mg/L), TSS (100 mg/L), and O&G (5 mg/L). However, pH and temperature passed the Class C effluent standards both untreated and treated wastewater.

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IV. Conclusion

This study assessed the efficiency of treating slaughterhouse wastewater using coco fiber media in a fixed-bed biofilm reactor (FBBR), focusing on BOD_5, TSS, and oil and grease (O&G) removal across six trials. The raw wastewater was highly contaminated, with BOD_5 ranging from 945 to 4,260 mg/L, TSS from 46 to 370 mg/L, and O&G from 74 to 249 mg/L—exceeding the DENR DAO 2016-08 Class C limits. Coco fiber media achieved high removal efficiencies: 98.89% for BOD_5, 91.42% for TSS, and 92% for O&G, attributed to effective biofilm formation. Kaldnes K1 (control media) also performed well in BOD_5 (up to 97.25%) and O&G (up to 89.18%) removal but showed variability in TSS, including negative efficiencies due to operational turbulence. Statistical tests revealed no significant difference between the media for BOD_5 ($p = 0.3039$), TSS ($p = 0.47152$), and O&G ($p = 0.57548$) removal, though coco fiber showed slightly better performance overall. Neither media consistently met Class C effluent standards for BOD_5, TSS, and O&G. However, pH and temperature remained within acceptable limits throughout. The results suggest coco fiber is a viable, sustainable, and cost-effective alternative to conventional bio-carrier media in wastewater treatment.

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