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Experimental Investigation of Wastewater by Using Novel *Borassus flabellifer* Fiber and *Cocos nucifera* Fiber

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Abstract: This research work deals with the treatment of domestic wastewater by using novel *Borassus flabellifer* fiber and *Cocos nucifera* fiber. Both fibers act as filter media for the treatment process. It has been gradually the removal efficiency of bio-chemical oxygen demand. Scanning Electron Microscopy, Energy X-ray Dispersive, and Fourier Transform Infrared Spectroscopy analysis were done to characterise the novel fiber. The wastewater sample was analysed for BOD, COD, chloride, oil and grease, sulphate, total nitrogen, phosphate, total dissolved solids, and total suspended solids. The sample was treated with natural fibrous materials as fixed aerated beds. The depth of filter media was 15 cm for *Borassus flabellifer* fiber and *Cocos nucifera* fiber. When the process is done, the BOD removal percentage of novel *Borassus flabellifer* fiber is 90.71% and *Cocos nucifera* fiber is 66.60%. SPSS carried out has a significance of 0.224 ($P < 0.5$). The mean BOD values of groups 1 and 2 are 84.75 and 304.87, respectively. Similarly, the standard deviation is 0.35410 and 0.78486, respectively. The novel *Borassus flabellifer* would perform better BOD removal than *Cocos nucifera*.

Key words: *Borassus flabellifer*, *Cocos nucifera*, wastewater, filtration, biochemical oxygen demand.

Introduction

Urban centers, which comprise more than 50,000 people in Class 1 and Class 2 cities and towns (making up over 70% of all urban populations), are anticipated to produce roughly 38,254 MLD (million liters per day) of wastewater. About 11,787 MLD, or around 31% of the wastewater generated in these two groups of metropolitan centers, can currently be treated by municipal wastewater systems. Over the years, metropolitan centers' capacity for producing wastewater and treating it changed (Aishwarya et al., 2023; Anusuya et al., 2017; Basha et al., 2023; Etier et al., 2020). Population expansion will cause the demand for freshwater to become unmanageable for all applications. Forecasts indicate that by 2051, urban wastewater could amount to 120,000 MLD, and considering water supply plans for rural communities, rural India will also produce at least 50,000 MLD. Plans for wastewater management do not, however, take into account the growing rate of wastewater production (Faruk et al., 2014; Govindaraj et al., 2023a; Govindaraj et al., 2023b).

Central Pollution Control Board (CPCB) research indicates that of India's 269 operating Sewage Treatment Plants (STPs), the treatment capacity represents only 21 per cent of the country's total sewage generation. Rivers and lakes are mostly contaminated by sewage that hasn't been treated (Govindaraj et al., 2023c; Govindaraj et al., 2022; Ibrahim et al., 2012; Kalavathy and Lima

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Rose, 2008; Kavin and Janagan, 2019). The majority of Sewage Treatment plants constructed under Central Funding initiatives, including the Ganga Action Plan and Yamuna Action Plan of the National River Action Plan, are not fully operational. In contrast to water treatment, where it is utilized to make surface water fit for human consumption, wastewater treatment uses filtration to create high-quality effluent that can be used for a variety of purposes (Latha et al., 2023a; Latha et al., 2023b). There are several potential solutions, including trickling filters in treatment facilities, horizontal rock filters in contaminated streams, granular activated carbon (GAC), or sand filters in water treatment facilities (Latha et al., 2024; Latha et al., 2023c).

Materials and Methods

Sample Collection

Arakkonam is a municipality in Tamil Nadu's Ranipet district. The population of Arakkonam is estimated to be over 2 lakh people as of the 2021 census. Between 7.5 and 9 MLD of wastewater are produced. Since there is a drainage system in place for the collection and disposal of sewage, sewage is discharged from individual homes directly into the drain. Over the course of 15 days, sampling was done between 5.30 pm and 6.30 pm. Grab samples were obtained in distilled water-rinsed polypropylene cans. In the TNHB of the municipality of Arakkonam, a sample was taken from an open drain channel, and the treatment procedure was completed.

Borassus flabellifer Fiber

The wine palm, or *Borassus flabellifer*, is a species of Borassus that is indigenous to South Asia and Southeast Asia. The 3m-long, fan-shaped leaves have strong, black teeth along the petiole margins. The blossoms mature into meaty fruits that are 15–25 cm in diameter and with 1–3 seeds each. The seeds are encased within a woody endocarp, and the fruits range in colour from black to brown with a delicious, fibrous pulp (Latha et al., 2023d). Young palmyra seedlings develop slowly during the establishing period, barely generating a few leaves each year, but at some unspecified later point, they grow quickly and produce a considerable stem. After gathering the fruit from the palm trees, the fibers are removed. Salt, acetic acid, sodium acetate, soda ash, stabiliser, hydrogen peroxide, wetting agent, sequestering agent, and levelling agent are employed along with reactive and basic colours. The mature fruits are initially gathered (Peng et al., 2020; Rahman et al., 2018; Sangeetha et al., 2021; Sherman 2006). The husk is then scraped off. Fiber is used to separate the seeds from one another (Figure 1).

Figure 1: ***Borassus flabell*ifer linn.**

Cocos nucifera Fiber

The only remaining variety of the group Cocos is the coconut tree (*Cocos nucifera*), which belongs to the *Arecaceae* family of palm trees. They are common in tropical coastal areas and are considered a cultural symbol of the region. In healthy soil, a tall coconut palm tree can yield up to 75 fruits a year, however, it usually yields less than 30. The exocarp, mesocarp, and endocarp are its three layers. The glossy outer layer, known as the exocarp, can range in colour from yellow-green to yellow-brown. The mesocarp is made of coir, a fiber with numerous conventional and industrial uses as shown in Figure 2.

Figure 2: ***Cocos nucifera.***

SEM-Analysis

A Scanning Electron Microscope (SEM), which offers elemental analysis, high-resolution images, and the potential to automatically measure thousands of fibers in just minutes, is typically used to image fibers. The Scanning Electron Microscope (SEM) is a potent and useful imaging tool of the modern day.

FTIR Analysis

A forensic examiner can use FTIR in conjunction with microscopy to simultaneously identify the material and receive detailed visual microscopic information. In order to identify and describe unknown materials FTIR analysis is utilized. Similar to Non-Dispersive Infrared (NDIR) analyzers. The idea behind FTIR spectrometers is that different gases absorb infrared light at frequencies specific to their own species. However, rather than being limited to a specific range of frequencies, measurements are done throughout a wide spectrum because FTIR spectroscopy is a dispersion method.

EDS Analysis

Electron Dispersive Spectroscopy (EDS) is used to analyse the fiber materials, and an overview of EDS spectra is given. It is sometimes known as EDX or XEDS. Specific surface investigations are available with the use of Energy Dispersive X-ray Spectroscopy (EDS). These techniques are commonly used to examine solder joints, identify contaminants, reverse engineer products, investigate product failures, and analyse material surfaces, among other activities. EDS takes advantage of the X-ray spectrum that a solid sample struck by a concentrated electron beam releases to achieve a localised chemical analysis.

Experimental Setup

For this research work, two different fiber packing materials, fiber from *Cocas nucifera* and *Borassus flabellifer* were used. The two glass reactors utilised in this study are 6 mm thick, 45 cm × 45 cm × 60 cm in size, and filled to a known depth of 15 cm with fibers from *Cocas nucifera* and *Borassus flabellifer* as shown in Figure 3. Reactors are made in a rectangular shape for batch operation and the downflow mode (Tofan et al., 2020; Venkatesan et al., 2022a). The dissolved oxygen level in both reactors is maintained using diffused aerators. Mesh, inlet and outlet pipes, and taps are utilised as accessories. Dairy sludge from Hassan Dairy was initially seeded into the reactor in a 1:1 ratio with Arakkonam TNHB effluent. These reactors were then continually aerated for seven days with diffused air pumps to allow the biomass in both reactors. After the biomass has fully grown on the surface of the fixed beds in both reactors, a known volume of wastewater (25L) is fed through the inlet pipe, and the average MLSS is maintained in both reactors. It is determined that the initial properties of the wastewater are used for the investigation.

Figure 3: *Borassus flabellifer* and *Cocos nucifera* fiber.

After reaching a DO concentration of 2.5 mg/L in both reactors, sampling was carried out every 24 hours up to a contact time of 72 hours (Venkatesan et al., 2022b; Venkatesan et al., 2023; Vinod and Mahalingegowda 2014). Standard analytical techniques are used to examine the parameters such as pH, COD, BOD, chloride, sulphate, nitrate, and phosphate for samples flowing from the output by Examination of Water and Wastewater (APHA, 23rd Edition).

Statistical Analysis

The statistical program to be utilized for the outcome analysis is SPSS version 23. This study's independent variables are nonexistent. Using SPSS software, analysis was performed using a bar chart and an independent sample t-test.

Result and Discussion

Surface Morphology

SEM analysis is a technique used to identify the surface morphology and structure of samples at high magnification. Prior to SEM analysis, the samples of *Borassus flabellifer* fiber and Cocos nucifera fiber would need to be properly prepared. For *Borassus flabellifer* fiber and Cocos nucifera fiber would involve drying and obtaining a solid sample, such as by freeze-drying or air-drying. The prepared *Borassus flabellifer* fiber and *Cocos nucifera* fiber samples would be loaded into the

SEM instrument for analysis (Wahi et al., 2013). SEM images would be captured at various magnifications to reveal different levels like 50 µm and 10 µm. as shown in Figures 4 and 5.

FTIR Spectroscopy

FTIR is a technique that provides information about the chemical composition and molecular structure of a substance. In *Borassus flabellifer* fiber the spectrum obtained will reveal characteristic absorption peaks corresponding to the functional groups present in the root, such as alcohols, phenols, aldehydes, ketones, and others as shown in Figure 6. Before filtration, the *Cocos nucifera* fiber sample can be analysed using FTIR to obtain its initial chemical fingerprint. FTIR analysis will provide a spectrum showing the characteristic absorption peaks and functional groups present in the sample as shown in Figure 7.

EDS Analysis

EDS analysis is a technique used to analyse the elemental composition of a sample. Prior to EDS analysis, the *Borassus flabellifer* fiber and *Cocos nucifera* fiber samples would need to be properly prepared. The prepared *Borassus flabellifer* and *Cocos nucifera* fiber samples would be loaded into an appropriate electron microscope equipped with an EDS detector. The EDS detector measures the energy and intensity of these X-rays, which are used to identify the elements and determine their relative abundance. EDS analysis generates spectra that show characteristic

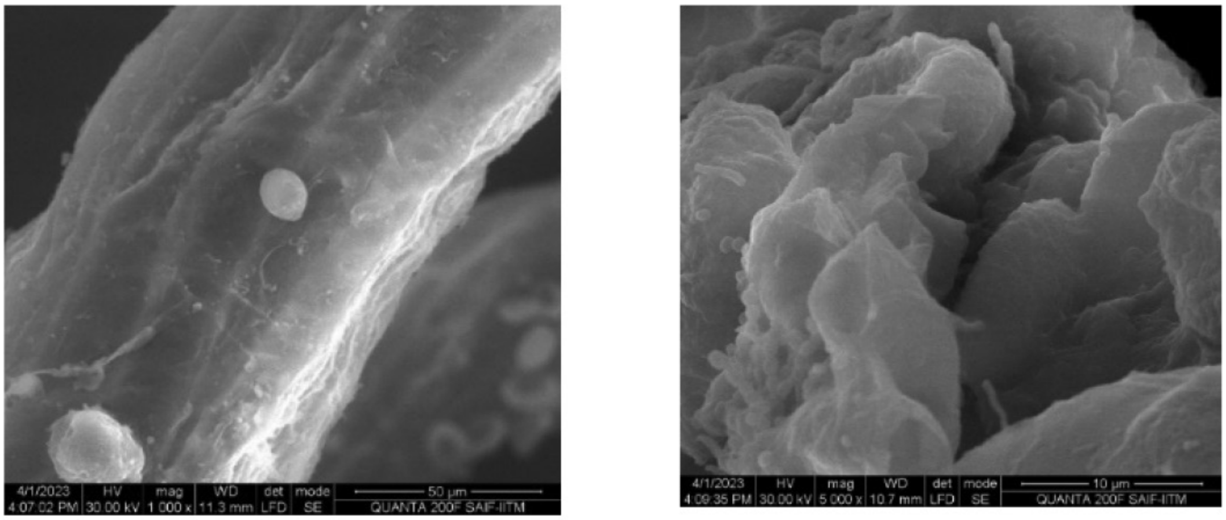

Figure 4: SEM images of *Borassus flabellifer*.

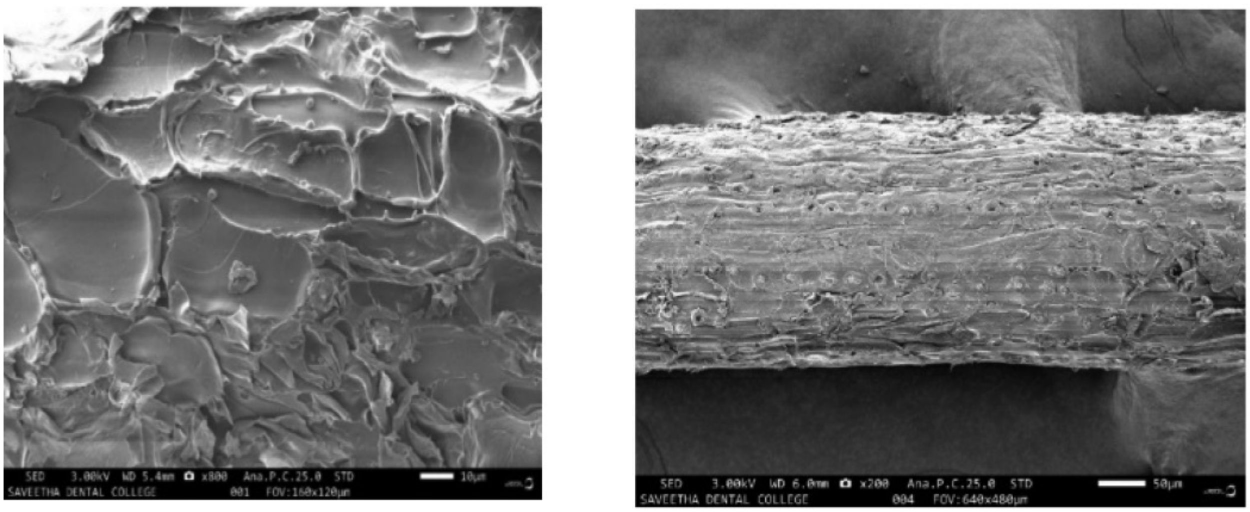

Figure 5: SEM images of *Cocos nucifera*.

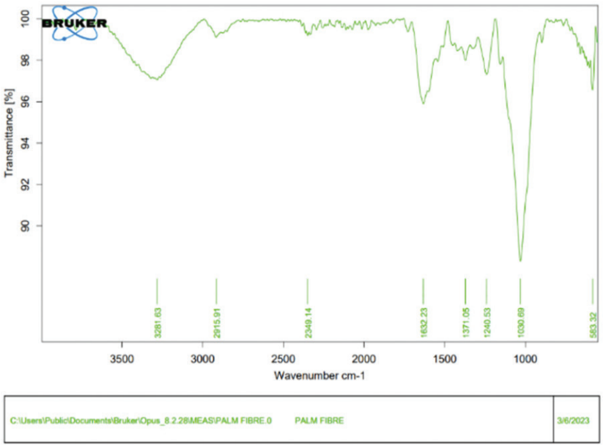

Figure 6: FTIR analysis of *Borassus flabellifer*.

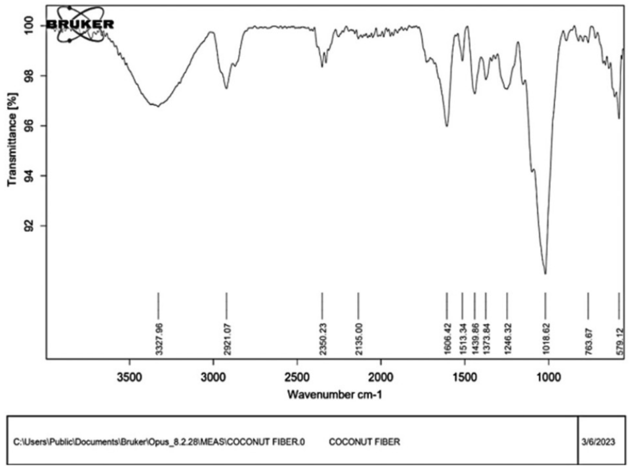

Figure 7: FTIR analysis of *Cocos nucifer.*

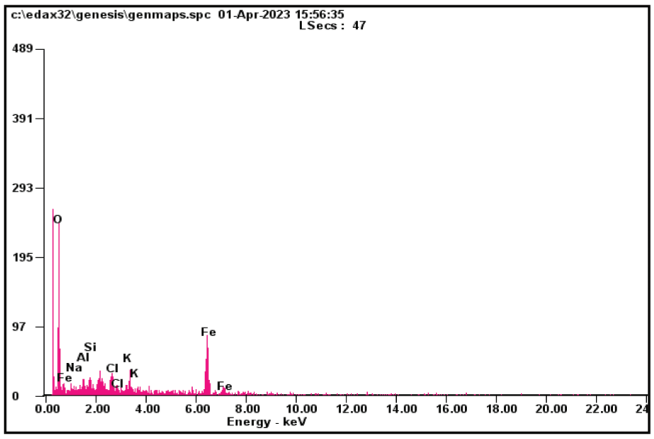

Figure 8: EDS analysis of *Borassus flabellifer.*

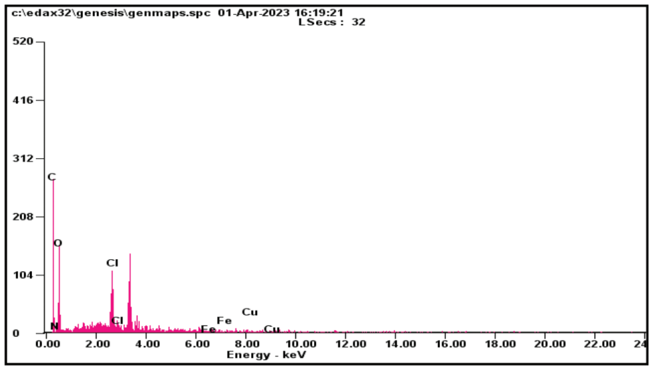

Figure 9: EDS analysis of *Cocos nucifera.*

peaks corresponding to the detected elements as shown in Figures 8 and 9.

Characteristics of Raw Effluent

The characteristics of raw effluent are essential to understanding wastewater treatment and Environmental Management. These characteristics play a crucial role in assessing the potential environmental impact and determining the appropriate treatment methods. Proper treatment and management of raw effluent are essential to protect and preserve our natural resources. The characteristics of the raw effluent are depicted in Table 1. The treatment method adopted in this work is filtration. The sample was treated using *Borassus*

Table 1: Raw effluent characteristics

S. No	*Parameter (mg/L)*	*Test method*	*Results*
1	BOD	IS 3025 (Part 44)	913
2	COD	APHA 23rd Edition:5220 B 2017	4166
3	Chloride	APHA 23rd Edition:4500 CI B 2017	543
4	Oil & Grease	APHA 23rd Edition:5220 2017	61
5	Sulphate	APHA 23rd Edition:4500 SO4E 2017	486
6	Total Nitrogen	SMSLA/EN/SOP/052	272
7	Phosphate	APHA 23rd Edition:4500 P BD: 2017	30
8	Total Dissolved Solids	APHA 23rd Edition:2540 C 2017	1820
9	Total Suspended Solids	APHA 23rd Edition:2540 D 2017	520

flabellifer linn fiber and *Cocos nucifera* fiber acted as filter media. Table 2 and Figure 10 represent the removal efficiency using *Borassus flabellifer* Linn fiber at a depth of 15 cm. Table 3 and Figure 11 represent the removal efficiency using Cocos nucifera fiber at a depth of 15 cm.

Table 2: Removal efficiency *Borassuss flabellifer* linn at 15 cm

S.No	*Parameters (mg/L)*	*Removal efficiency(%)*
1	BOD	90.25
2	COD	90.25
3	Chloride	44.19
4	Oil & Grease	77.04
5	Sulphate	26.54
6	Total Nitrogen	89.33
7	Phosphate	6.25
8	Total Dissolved Solids	35.71
9	Total Suspended Solids	44.61

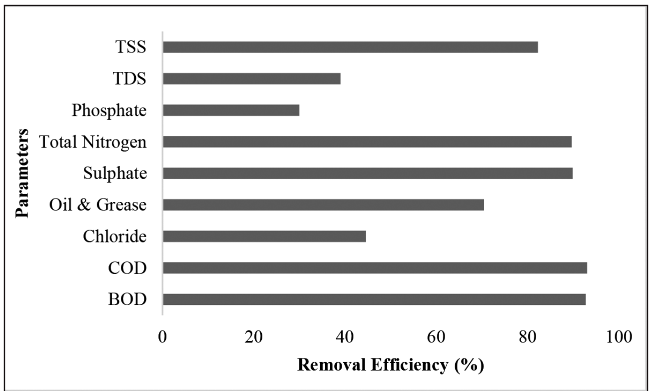

Figure 10: Graphical representation of removal efficiency by *Borassus flabellifer* Linn.

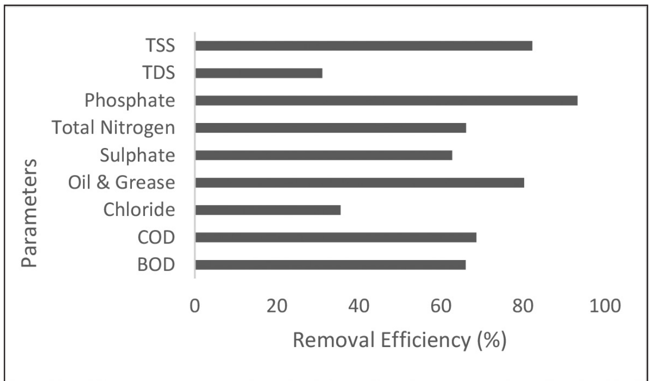

Figure 11: Graphical representation of removal efficiency by *Cocos nucifera*.

Table 3: Removal efficiency *Cocos nucifera* at 15 cm

S.No	*Parameters (mg/L)*	*Removal efficiency(%)*
1	BOD	66.04
2	COD	68.65
3	Chloride	35.54
4	Oil&Grease	80.32
5	Sulphate	62.75
6	TotalNitrogen	66.17
7	Phosphate	93.33
8	TotalDissolved Solids	31.09
9	TotalSuspendedSolids	82.30

Table 4: Result of BOD removal in *Borassus flabellifer* fiber

S. No	*Borassus flabellifer*	
	BOD removal in mg/L	*BOD removal in percentage*
1	88	90.36
2	85	90.69
3	86	90.58
4	85	90.69
5	78	91.45
6	82	91.01
7	88	90.36
8	89	90.25
9	79	91.34
10	81	91.12
11	86	90.58
12	88	90.36
13	87	90.47
14	85	90.69
15	84	90.79
16	85	90.69
	Mean	90.71

BOD Removal

Table 4 shows the result of BOD removal in novel *Borassus flabellifer* fiber. The novel *Borassus flabellifer* fiber has the maximum BOD removal percentage as 91.45%. Moreover, the mean of BOD removal is 90.71%. Table 5 shows the result of BOD removal in *Cocos nucifera* fiber. The *Cocos nucifera* fiber has a maximum BOD removal level of 68.05%. And

Table 5: Result of BOD removal in *Cocos nucifera* fiber

S.No	*Cocos nucifera*	
	BOD removal in mg/L	*BOD removal in percentage*
1	305	66.59
2	310	66.04
3	302	66.92
4	306	66.48
5	297	67.46
6	296	67.57
7	320	64.95
8	315	65.49
9	310	66.04
10	292	68.01
11	302	66.92
12	299	67.25
13	306	66.48
14	304	66.70
15	310	66.04
16	304	66.70
Mean		66.60

the mean BOD removal is 66.06%. Table 5 shows a statistical analysis of the comparison novel *Borassus flabellifer* and *Cocos nucifera*. Table 6 shows an independent sample T-test performed for the two groups for significance and standard error determination of BOD removal between novel *Borassus flabellifer* and *Cocos nucifera* fiber (Figure 12). Table 7 depicts the independent sample test.

Conclusion

Borassus flabellifer Linn was used as filter material for a 15 cm depth, and the removal efficiency of BOD and COD was determined to be 90.25% and 90.25%, respectively. It was discovered that employing *Cocos nucifera* as filter material for a 15 cm depth resulted in removal efficiencies of BOD and COD of 66.04% and 68.65%, respectively. However, it was shown that *Borassus flabellifer* Linn Fibers had greater treatment efficiency than *Cocos nucifera* Fibers. The wasted fibers can be utilised as organic manure because they are high in nutrients. Because natural fibers are so readily available, this method is simple to implement. The removal efficiency is effective for wastewater treatment in smaller areas. A comparative analysis between the novel *Borassus flabellifer* and *Cocos nucifera* was done. From the result obtained, it is observed that the novel *Borassus flabellifer* has more BOD removal hence

Figure 12: Bar plot showing the BOD removal (mg/L) plotted for the two groups considered, *Borassus flabellifer* and *Cocos nucifera.*

Table 6: Statistical analysis of *Borassus flabellifer* and *Cocos nucifera*

Parameter	*Group*	*N*	*Mean*	*Std. deviation*	*Std. error mean*
BOD	*Borassus flabellifer*	16	90.7144	0.35410	0.08852
	Cocos nucifera	16	66.6025	0.78486	0.19622

Table 7: Independent sample T for removal of BOD between novel *Borassus flabellifer* and *Cocos nucifera*

Independent sample t-test										
		Levene's test for equality of variance		*T-test for equality of means*						
		F	*Sig*	*t*	*Df*	*Sig. (2-tailed)*	*Mean difference*	*Std error difference*	*95% confidence interval of the difference*	
									Lower	*Upper*
BOD	Equal variances assume	5.597	0.025	112.0	30	0.000	24.111	0.21526	23.6722	24.55150
	Equal variances not assume			112.0	20.8	0.000	24.111	0.21526	23.6640	24.55971

compared with the *Cocos nucifera*. The BOD removal percentage of novel *Cocos nucifera* is 66.6% and *Borassus flabellifer* is 90.71%. SPSS carried out has a significance of 0.224 ($P < 0.5$). The mean BOD values of groups 1 and 2 are 84.75 and 304.875, respectively. Similarly, the standard deviation is 0.35410 and 0.78486, respectively. Therefore, it can be concluded that the novel *Borassus flabellifer* is the better choice for purifying the water through the filtration process.

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Contribution of Authors:

Conceptualisation: A. Latha, Methodology: R. Ganesan, Analysis and Investigation: R. Ganesan and P. Kavitha. Writing - original draft preparation: A. Latha and Venkatesan G. Writing - review and editing: P. Kavitha and Venkatesan G.

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