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Sustainable College Wastewater Recycling: Enhancing Treatment Efficiency with Natural Fiber Filtration

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ABSTRACT

Water scarcity is a growing concern worldwide, making wastewater recycling an essential approach for sustainable water management. This study focuses on the treatment and recycling of sewage water generated at Malla Reddy Engineering College and Management Sciences, Medchal, using natural fiber materials as an eco-friendly filtration medium. The primary objective is to enhance the efficiency of wastewater treatment while promoting sustainability within the college campus.

The major sources of wastewater in the college include hostel buildings, the canteen, administrative offices, classrooms, and laboratories. If left untreated, this wastewater can lead to severe environmental pollution and health hazards. Conventional wastewater treatment methods are often costly and require significant energy input. In contrast, this study explores the potential of natural fibers Agave sisalana fibers and Areca husk fibers—as an affordable and sustainable alternative for filtering wastewater. These fibers possess excellent adsorption and filtration properties, making them effective in removing contaminants from sewage water. The research involves collecting raw wastewater samples and treating them with Agave sisalana and Areca husk fibers at different contact durations. The efficiency of this treatment method is assessed by comparing the raw and treated water samples based on key water quality parameters, including pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), chloride, sulfate, and nitrate levels. The results highlight a significant improvement in water quality, demonstrating the effectiveness of natural fiber filtration in wastewater treatment. The findings of this study emphasize the potential of natural fiber-based wastewater treatment as an innovative and cost-effective approach to improving water quality on college campuses. By implementing this method, institutions can not only reduce their environmental footprint but also contribute to water conservation efforts. This approach aligns with sustainable development goals and provides an efficient, low-cost solution for wastewater treatment in educational institutions and similar setups. Future research can focus on optimizing the fiber composition and exploring its application on a larger scale.

Keywords: Wastewater Recycling, Natural Fiber Filtration, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Eco-friendly Filtration.

1. INTRODUCTION

Wastewater is liquid waste discharged by domestic residences, commercial properties, industry, agriculture, which often contains some contaminants that result from the mixing of wastewater from different sources. Wastewater obtained from various sources need to be treated very effectively in order to create a hygienic environment. If proper arrangements for collection, treatment and disposal of all the waste produce from city or town are not made, they will go on accumulating and create a foul condition that the safety of the structures such that building, roads will be damaged due to accumulation of wastewater in the foundations. In addition to this, disease causing bacteria will breed up in the stagnant water and the health of

the public will be in danger.The principal aim of wastewater treatment is generally to allow human and industrial effluents to be disposed of without danger to human health or unacceptable damage to the natural environment. Therefore in the interest of the community of the town or city it is most essential to collect, treat and dispose of all the wastewater of the city in such a way that it may not cause harm to the people residing in the town. The extent and the type of treatment required, however depends on the character and quality of both sewage and sources of disposal available.The sewage after treatment may be disposed either into a water body such as lakes, streams, river, estuary and ocean or into land. It may be used for several purposes such as conservation, industrial use or reclaimed sewage effluent in cooling systems, boiler feed, process water, reuse in agriculture, horticulture, sericulture, watering of lawns. Wastewater reuse is becoming increasingly popular, especially in geographies where potable water is in short supply. Reduction of strength of domestic wastewater using two different bed materials Areca Husk fibre and Agava sisalana fibre as a filter media is one such type of treatment method adopted. The utilization of fixed films for wastewater treatment process has been increasingly considered due to inherent advantages over suspended growth system. The present work is intended to study the application of the comparative study between the fibres ie., Areca fibre and Agava sisalana as a fixed bed for treating domestic wastewater and to know the comparative removal efficiency of COD, BOD, nitrate, sulphate, chloride with conventional gravel bed in a small volume reactor.

2. LITERATURE REVIEW

Kudaligama et al. 2015, did a study on “Effect of Bio-brush medium: a coir fibre based biomass retained on treatment efficiency of an anaerobic filter type reactor”, which reveals that the efficiency of treatment increased with increase in SSA of the media and proper calibration of OLR in the reactor. Kevin M. Sherman et al. 2006, did a study on “Introducing a new media for fixed film treatment in Decentralied Wastewater systems”, which reveals that Quanics .Inc . has patented a product that combines adavantages of both naturally and artificially occuring media. The product has successfully passed NSF Standard 40 certification.

Padmini et al.2008, Surface modified Agava sisalana as an adsorbent for removal of nickel from aqueous solutions- Kinetics and Equilibrium studies. The studies reveals that the Sisal fibre can be considered to be a cheap and viable adsorbent for the removal of nickel from aqueous solution.

Vinod et al. 2013, did a study on “Studies on natural fibrous material as submerged aerated beds for wastewater treatment”, which reveals that the maximum percentage reduction of COD(73%), BOD_5(80%), and Orthophosphate(82%) with increased retention time in both reactors. The used of natural fibrous materials as fixed bed in WWT shows promising removal efficiency of organic and nutrients.

Shivakumaraswamy G.R et al. 2013, did a study on “Domestic wastewater treatment in reactors filled with areca husk fibres and pebble bed”, which reveals that Areca husk fibres could be applied as an alternative medium to gravel bed for packed bed filters for the treatment of domestic wastewater since removal of COD, BOD and NH_3 were 299,31.5 and 27.89mg/L. Vinod A.R et al. 2014, did a study on “ Treatability studies of selective fibrous packing medias for sewage treatment”, which reveals that the coconut coir packing density 40kg/m^3 showed higher removal efficiency of organic matter and nutrients in comparison to 70kg/m^3. Cost effective and locally available medias such as coconut coir fibres, coffee husk can be used as an alternative option for sewage treatment.

Gulhaane M.L. et al. 2017, did a study on “Performance of the modified multi-media filter for domestic wastewater treatment”, which reveals that the multi-media maybe considered as efficient pre-treatment process for wastewater treatment. The media enhance the performance of treatment system, and this technology is environment friendly and cost effective.

Bharati Sunil et al. 2015, did a study on “Coconut coir: A media to treat the wastewater”, which reveals that naturally available low cost media proves essentially a best option to industrialists to prevent the environmental pollution. Coconut coir fibre is rich in cellulose and lignin, having a high specific area and wetting ability factor which are essential for bacterial adhesion in fixed film processes.

3. PROPOSED SYSTEM

In our present study we have checked the feasibility of Agava sisalana and Areca husk fibres as filter media for wastewater treatment. Wastewater quality analysis have been conducted in the laboratory for parameters such as BOD, COD, chlorides, nitrates, sulphates.

3.1 COLLEGE WASTE WATER

Sree Dattha Institute of Engineering and Science, Sheriguda, Hyderabad, Telangana. In the college so many different blocks was there those are administrative block, department blocks, laboraties blocks, canteen, R&D cell, hostel blocks, auditorium etc from this the quantity of wastewater being generated is 1.5 MLD. The sewage is discharged from individual blocks connected to drainage pipes these pipes are directly into the manhole. The manhole directly into the open drain, since there is a under drainage system for the collection and disposal of sewage in term of manhole in the college.

3.2 SAMPLING

Sampling was conducted for every 72 hours for a period of 15 days between 5:30 pm to 6:30pm. Grab samples were collected in plastic cans rinsed with distilled water. Sample was collected from the manhole, in SDIE College and the treatment process was carried out.

Samples were analysed for the following parameters:

1. BOD
2. COD
3. Chloride
4. Sulphate
5. Nitrate
6. pH

FIG 3.1: College manhole

3.3 METHODOLOGY

- Two different fibrous packing materials used for the present study, Agave sisalana and Areca husk fibre.
- Two reactors used in this study, are made of 6mm glass, having dimensions 45cm x45cm x60 cm, filled with agave sisalana and areca husk fibres for a known depth of 15 cm.
- Reactors are rectangular in shape and fabricated for down flow mode and for batch operation process.
- Diffused aerators are used to maintain the dissolved oxygen level inside both the reactors.
- Accessories such as mesh, Inlet and outlet pipes and taps are used.
- These reactors were then aerated with diffused air pumps continuously for 7 days for acclimatization and development of biomass in both the reactors.
- After the complete growth of biomass on the surface of fixed beds in both reactors, known volume (25L) of wastewater is fed through inlet pipe and MLSS is kept constant at an average in both the reactors.
- The initial characteristics of the wastewater used for the study is determined.
- The sampling was done after attaining a DO concentration 2.5mg/L in both reactors at an interval of 24hours up to a contact time of 72 hours.

- The parameters such as pH, COD, BOD5, chloride, sulphate, nitrate are analyzed for the samples coming from the outlet by implementing standard methods for the Examination of Water and Wastewater.

FIG 3.3: INITIAL SET-

FIG 3.4: SEEDING (Sludge and wastewater ratio(1:1) for 15cm depth fibres)

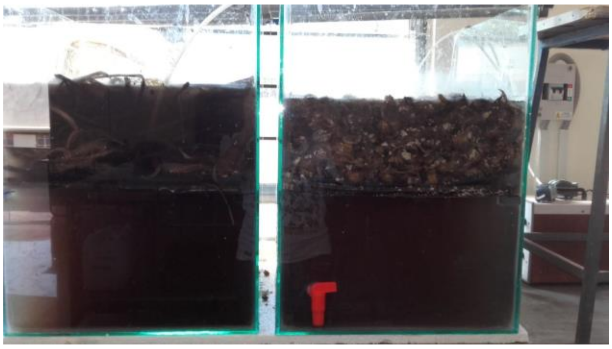

FIG 3.5: SETUP SHOWING 30cm DEPTH FIBRES

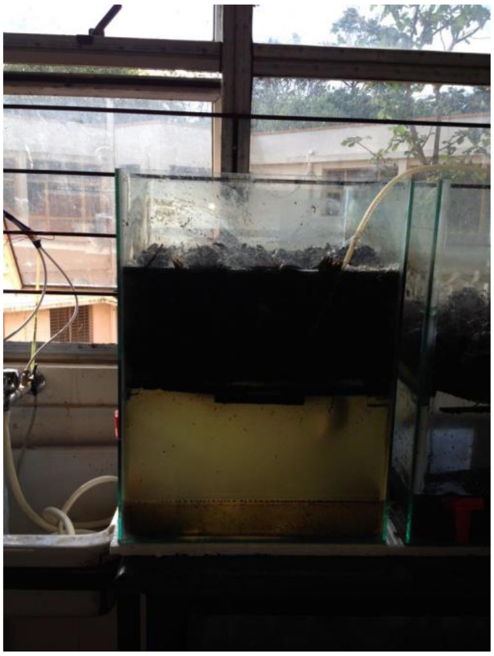

FIG 3.6: MIXED MEDIA WITH 30cm DEPTH

4. RESULTS AND DISCUSSIONS

4.1 TABULATIONS AND GRAPHS

Table 4.1: Removal efficiency using 15cm Agava sisalana filter bed

Parameters	Initial	1st Day	Removal Efficiency (%)	2nd Day	Removal Efficiency(%)	3rd Day	Removal Efficiency(%)
BOD(mg/L)	200	175	12.5	120	40	92	54
COD(mg/L)	250	201	19.6	151	39.6	125	50
Chloride(mg/L)	27	19	29.63	15	44.44	12	55.5
Sulphate(mg/L)	1.3	1.0	23.076	0.92	29.23	0.78	40
Nitrate(mg/L)	1.1	0.7	36.36	0.65	40.9	0.58	47.27
pH	7.3	7.4		7.3		7.3	

Table 4.2: Removal efficiency using 15cm Areca husk filter bed

Parameters	Initial	1st Day	Removal Efficiency(%)	2nd Day	Removal Efficiency(%)	3rd Day	Removal Efficiency(%)
BOD(mg/L)	200	150	25	132	34	105	47.5
COD(mg/L)	250	190	24	152	39.2	132	47.2
Chloride(mg/L)	27	22	18.51	16	40.74	13	51.85
Sulphate(mg/L)	1.3	1.1	15.38	1.01	22.3	0.82	36.92
Nitrate(mg/L)	1.1	0.96	12.72	0.72	34.54	0.61	44.54
pH	7.3	7.35		7.4		7.4	

Table 4.3: Removal efficiency using 15cm Agava sisalana filter bed

Parameters	Initial	1st Day	Removal Efficiency (%)	2nd Day	Removal Efficiency(%)	3rd Day	Removal Efficiency(%)
BOD(mg/L)	140	99	29.2	87	37.8	75	46.4
COD(mg/L)	179	124	30	107	40.2	95	46.9
Chloride(mg/L)	61.49	42	31.9	39	36.06	32	47.5
Sulphate(mg/L)	1	0.68	32	0.42	58	0.21	79
Nitrate(mg/L)	1	0.57	43	0.11	89	NIL	100
pH	7.5	7.52		7.41		7.41	

Table 4.4: Removal efficiency using 15cm Areca husk filter bed

Parameters	Initial	1st Day	Removal Efficiency (%)	2nd Day	Removal Efficiency	3rd Day	Removal Efficiency (%)
BOD(mg/L)	140	101	27.8	89	36.4	77	45
COD(mg/L)	179	125.5	29.8	111	37.9	96.2	46.2
Chloride(mg/L)	61.49	42	31.1	36	40.9	34	44.2
Sulphate(mg/L)	1	0.57	43	0.37	63	0.21	79
Nitrate(mg/L)	1	0.54	46	0.12	88	NIL	100
pH	7.6	7.62		7.7		7.7	

Table 4.5: Removal efficiency using 30cm Agava sisalana filter bed

Parameters	Initial	1st Day	Removal Efficiency(%)	2nd Day	Removal Efficiency(%)	3rd Day	Removal Efficiency(%)
BOD(mg/L)	320	208	35	189	40.9	120	62.5
COD(mg/L)	398	260	34.6	237	40.4	151	62
Chloride(mg/L)	70	49	30	37	47.1	27	61.4
Sulphate(mg/L)	1	0.44	56	0.01	99	NIL	100
Nitrate(mg/L)	1	0.68	32	0.32	68	0.1	90
pH	7.7	7.6		7.7		7.5	

Table 4.6: Removal efficiency using 30cm Areca husk filter bed

Paramters	Initial	1st Day	Removal Efficiency(%)	2nd Day	Removal Efficiency(%)	3rd Day	Removal Efficiency(%)
BOD(mg/L)	320	221	30.9	177	44.68	125	61
COD(mg/L)	398	276	30.6	220	44.72	157	60.5
Chloride(mg/L)	70	44	37.1	38	45.7	29	58.5
Sulphate(mg/L)	1	0.58	42	0.02	98	NIL	100
Nitrate(mg/L)	1	0.59	41	0.29	71	0.12	88
Ph	7.7	7.7		7.6		7.6	

Table 4.7: Removal efficiency using 30cm Agava sisalana filter bed

Parameters	Initial	1st Day	Removal Efficiency (%)	2nd Day	Removal Efficiency (%)	3rd Day	Removal Efficiency (%)
BOD(mg/L)	335	219	34.6	139	58.5	110	67.1
COD(mg/L)	419	271	35.3	170	59.4	133	68.2
Chloride(mg/L)	73	51	30.1	39	46.5	27	63

Sulphate(mg/L)	1.02	0.32	68.6	0.01	99	NIL	100
Nitrate(mg/L)	1.1	0.47	57.2	0.2	81.8	NIL	100
Ph	7.6	7.6		7.7		7.6	

Table 4.8: Removal efficiency using 30cm Areca husk filter bed

Parameters	Initial	1st Day	Removal Efficiency (%)	2nd Day	Removal Efficiency (%)	3rd Day	Removal Efficiency (%)
BOD(mg/L)	335	227	32.2	155	53.7	119	64.4
COD(mg/L)	419	280	33.1	191	54.4	145	65.3
Chloride(mg/L)	73	50.5	30	41	43.8	27.5	62.3
Sulphate(mg/L)	1.02	0.4	60.7	0.03	97	NIL	100
Nitrate(mg/L)	1.1	0.51	53.6	0.1	90.9	NIL	100
pH	7.6	7.5		7.6		7.6	

Table 4.9: Removal efficiency using combined filter beds

Parameters	Initial	1st Day	Removal Efficiency(%)	2nd Day	Removal Efficiency(%)	3rd Day	Removal Efficiency(%)
BOD(mg/L)	420	225	46.4	160	61.9	97	77
COD(mg/L)	529	280.2	47	195	63.1	120	78
Chloride(mg/L)	81	46	43.2	37	54.3	19	76.5
Sulphate(mg/L)	1	0.45	55	0.01	99	NIL	100
Nitrate(mg/L)	1.02	0.6	41.2	0.1	90.1	NIL	100
Ph	7.6	7.5		7.6		7.6	

4.2 COMPARISON OF AGAVA SISALANA AND ARECA HUSK FIBRES

3 days Removal Efficiency (%):

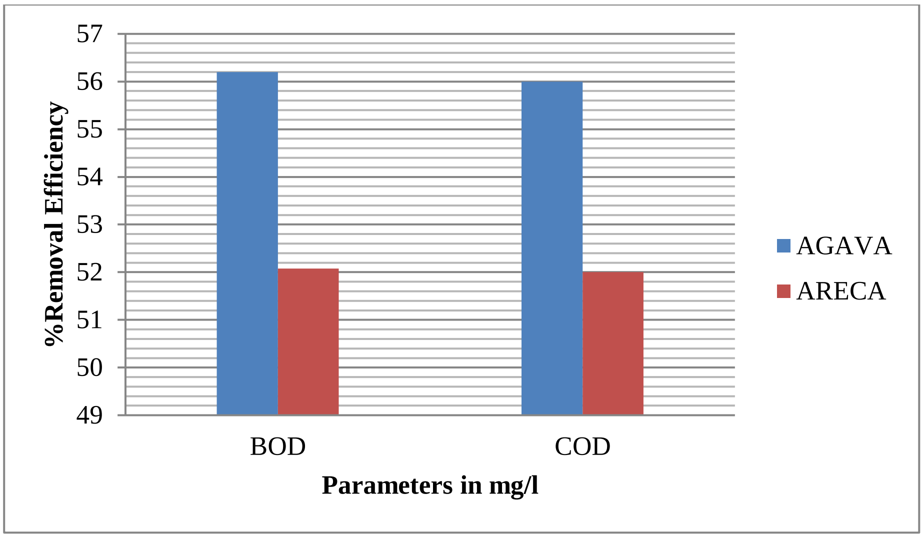

FIG 4.15: Comparison of BOD and COD Removal Efficiency (15cm depth)

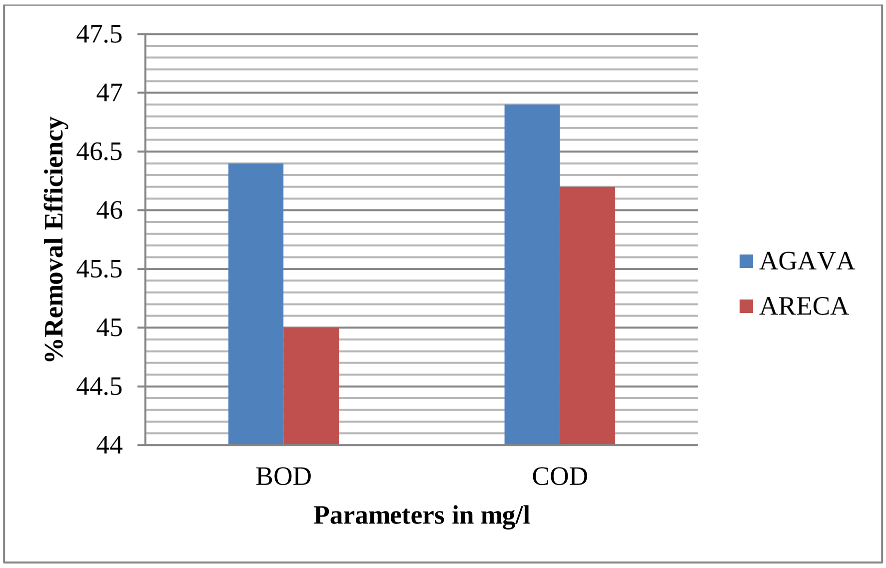

FIG 4.16: Comparison of BOD and COD Removal Efficiency (15cm depth)

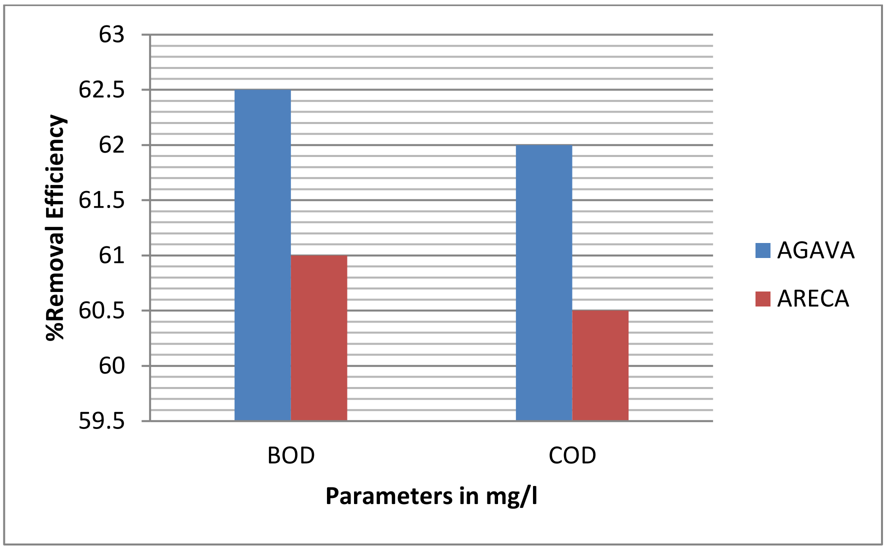

FIG 4.17: Comparison of BOD and COD Removal Efficiency (30 cm depth)

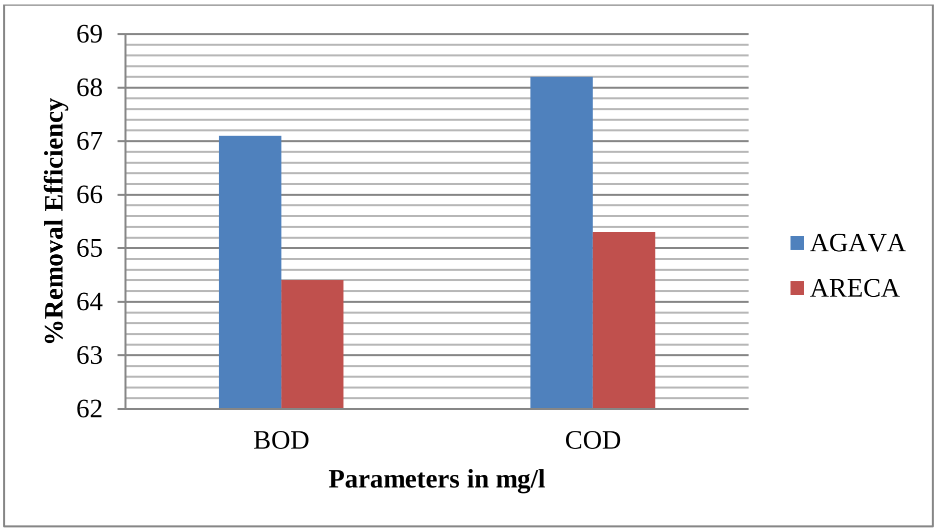

FIG 4.18: Comparison of BOD and COD Removal Efficiency (30 cm depth)

Figure 4.15, figure 4.16, figure 4.17, figure 4.18 shows the comparison study of Agava sisalana and Areca husk fibres. It can be seen that the removal efficiency of BOD and COD using Agava sisalana fibre is found to be higher than Areca husk fibre in the above figures.

4.3 COST ANALYSIS

Table 4.19: Cost analysis of Agava sisalana and Areca husk fibre

Characteristics	Processing cost	labour fees	Transportation cost	Total cost
Agava sisalana(4kg)	20/-	50/-	50/-	120/-
Areca husk(4kg)	-	20/-	50/-	70/-

- **Aerators**: Four numbers of aerators were used having capacity: 2x1.5 litres/minute
- **Power:** 4W, volt: 220-240V, frequency: 50 Hz and costing Rs.150 each.

Therefore the cost for treating 25 litres of wastewater using Agava sisalana and Areca husk fibres in the submerged aerated bed is found to be Rs.79/-

5. CONCLUSIONS

The study demonstrated a considerable reduction in Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and key nutrients such as nitrates, sulfates, and chlorides after treating wastewater using natural fiber filtration. This indicates the effectiveness of Agave sisalana and Areca husk fibers as sustainable filter media for wastewater treatment. When comparing the removal efficiency of the two fiber materials, it was observed that Agave fibers performed better than Areca fibers. At a filter depth of 15 cm, the removal efficiency of BOD and COD using Agave fibers was 56.2% and 56%, respectively, whereas Areca fibers achieved a slightly lower efficiency of 52.08% and 52%, respectively. When the filter depth was increased to 30 cm, Agave fibers exhibited a higher removal efficiency of 67.1% for BOD and 68.3% for COD, compared to Areca fibers, which achieved 61% and 61.5%, respectively. Additionally, when both fiber materials were combined as a dual-filter media, the removal efficiency further increased, reaching 77% for BOD and 78% for COD, highlighting the advantage of using a combination of natural fibers for enhanced treatment performance. One of the challenges encountered during the study was the foul odor emission caused by the early decomposition of the fibers. This suggests the need for further optimization in the fiber preparation and maintenance process to minimize odor-related issues.

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