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Studies on natural fibrous materials as submerged aerated beds for wastewater treatment

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ABSTRACT

The use of various fixed beds having higher surface area is effective in removing organic matters and nutrients from municipal wastewater. Due to the higher specific surface area, fibrous materials are often considered a better choice for increased microbial support and treatment efficiency. In the present study two naturally available fibrous materials such as sisal and Oil palm Empty fruit Bunch (OPEFB) fibers having higher specific surface area were used as packing media in two different bio-reactors for sewage treatment, under batch mode and similar experimental conditions. Experimental results obtained were satisfactory at a packing density of 50 kg/m^3. The reactors were continuously aerated for different contact times. At a contact time of 72 hours and Mixed Liquor Suspended Solids(MLSS) concentration ranging from 1500-2000 mg/L, the reactors filled with Sisal and OPEFB fibers shows satisfactory COD removal of 69.5% and 73%, BOD_5 of 74% and 79.7%, NH_3-N of 69% and 72.7%, and Ortho-phosphate of 81% and 82.3% respectively. The study reveals that these fibrous medias could be acceptable for efficient removal of organics and nutrients present in the sewage.

Introduction

The production of organic wastes is an integral part of a developed society. The most common method usually adopted by most of the residential or small-scale commercial units in India is either to discharge the wastewater onsite or drain it into any public wastewater carriage systems. It is also obvious that the setting up of conventional treatment systems for the above-mentioned situations may not be feasible due to the high cost of equipment and inadequate space for installation of these units [Praveen and Srilakshmy, 2008].

A biofiltration media consist of a reactor packed with solid material on which a biolayer formed by proper microbial populations [Mohammed suhail and Vijayan.]. Systems based on naturally occurring media include sand filters and peat-based biofilters. Artificial media include open cell foam, textiles, plastics, and recycled, ground glass. All such filters operate as fixed-film systems [Kevin M. Sherman, 2006].

Due to the higher specific surface area, fibrous materials are often considered a better choice for increased microbial support and treatment efficiency. In addition, high removal rates in BOD_5 (biochemical oxygen demand) levels and nutrients have also been observed in fiber-based reactors. Also, various studies have established the utility of polymer fiber geotextiles to support biofilm development and also augment the biodegradation rate. Besides higher biodegradation rate, the ability of the treatment unit to withstand sudden shock is also a vital requirement for any wastewater treatment operations. Hence it is reliable choice for a biofilter medium could be based on any naturally available fibrous material containing rich organic matter [Praveen and Srilakshmy, 2008]. Numerable investigations were carried out using synthetic fibrous materials as a fixed media in the wastewater treatment, but only limited efforts have been made to use natural fibrous materials such as Sisal and oil palm fruit bunch as submerged aerated bed. Natural fibers have low density, low relative cost and good biodegradability while polymers have high resistance to moisture and impact.

India has a vast resource for different natural fibers viz., jute, sisal, banana, coir etc., which are abundantly available in many parts. Presently, the production of natural fibers in India is more than 400 million tonnes. In the present study emphasis has been given for viable and cost effective technology by adopting naturally available fibrous materials such as sisal and oil palm empty fruit bunch (OPEFB) fibers as fixed bed for the sewage treatment .

Materials and Methodology

Fibrous bed material

Sisal is a leaf fiber derived from the plant Agave Sisalana. Sisal fiber is ligno-cellulosic in nature and the main properties of the fiber are summarized in Table 1.Oil Palm (*Elaeis guineensis*) is the most important species in *Elaeis* genus which belongs to the family Palmae. It is one of the most economical perennial oil crops for its valuable oil-producing fruits in tropical regions such as West Africa and Southeast Asia. Plate1 and 2 represents the oil palm empty fruit bunch, its fiber and sisal fibers. Table 2 shows the important properties of OPEFB fiber.

Extraction and preparation of Sisal and Oil palm Empty Fruit Bunch (OPEFB) fiber

Sisal fiber can be extracted from its leaves by retting. Water retting is a traditional biodegradation process involving microbial decomposition (breaking of the chemical bonds) of sisal leaves, which separates the fiber from the pith. The fibers are washed and processed further. OPEFB was obtained from palm oil mill, was then crushed by a crushing machine to yield

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the fiber. It is then separated from the fruits and bunch manually and then fibers were extracted by crushing. Then the extracted fibers were washed with distilled water in order to remove the salts, color etc, and sun dried. Sisal and OPEFB fibers with specific surface area ranging from 500-650m^2/m^3 were chosen for detailed experimental investigations to assess their capability with respect to the biological treatment process.

Reactors

Two rectangular laboratory scale reactors made of acrylic fiber one of size 450x450x600 mm^3, and another of 400x400x450 mm^3, were filled with sisal fiber (RS-1) and oil palm empty fruit bunch fibers (RP-2) with a packing density of 50 kg/m^3 and bed depth of 150 mm. The reactors were designed for down flow mode of operation and arrangements were made for the collection of treated wastewater. Suitable air diffusers located at the bottom of the reactors which produces fine air bubbles throughout the reactor in order to maintain aerobic condition. Wire meshes were used to support and fix the media to requisite depth. Fig.1 depicts the arrangement of reactors.

Table 1. Characteristics of sisal fiber used in Experiment (Source: Saira Taj, Munawar Ali Munawar, and Shafi ullah Khan, 2007)

Cellulose (Wt %)	66-78
Hemi-celluloses (Wt %)	12
Lignin (Wt %)	10-14
Pectin (Wt %)	10
Moisture Content (Wt %)	10-22
Width or Diameter (mm)	50-200
Density(g/cm^3)	1.5
Elongation (%)	2.0-2.5
Tensile strength(MPa)	511-635

Table 2. Characteristics of OPEFB fiber (Source: Kwei-Nam Law, Wan Rosli Wan Daud, and Arniza Ghazali,2007)

Cellulose (Wt %)	62.9±2.0
Hemicellulose (Wt %)	28.0
Lignin (Wt %)	19
Ash (%)	1.3±0.2
Fiber diameter (D), μm	19.1
Length- weighted fiber length, mm	0.99
Density (g/cm^3)	0.7-1.55
Elongation (%)	14
Tensile strength(MPa)	248

Plate 1: Photographic view of oil palm empty fruit bunch fibers

Plate 2: Photographic view of Sisal fiber

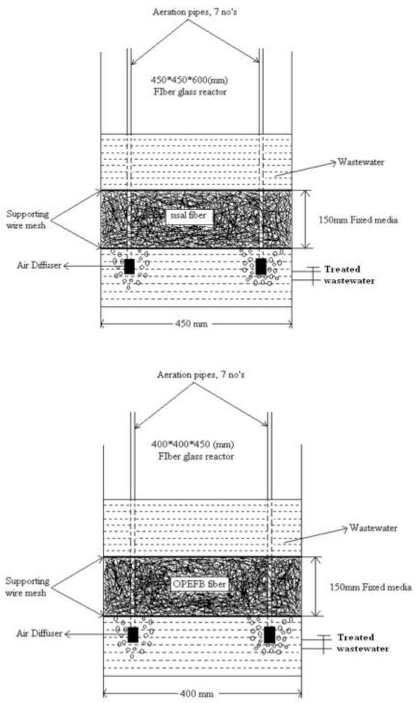

Fig. 1. Experimental Setup of reactors RS-1 and RP-2

Process Startup and System operation

The study has been carried out for a prefixed contact time. The domestic sewage sludge was collected and kept for aeration until it was used. Later sludge of around 25L was applied to the reactors containing the media of Sisal fiber (RS-1) and OPEFB fiber (RP-2). These reactors were then aerated with diffused air pumps continuously for 3 days in order to stabilize the reactor. Seeding was done from institutional boy's hostel wastewater and nutrient addition continued for eighteen days for the acclimatization and development of biomass in both the reactors. This is necessary because wastewater did not contain numerable microorganisms to initiate the process of biodegradation. On 20th day, after the complete growth of required biomass on the media 25L of wastewater was fed into the reactors. Continuous monitoring of aeration is done in order to maintain the aerobic conditions in the reactor. Both the reactors were running under batch mode of operation and the sampling is of grab type. Throughout the experiment, MLSS concentration of 1500 - 2000 mg/L was maintained. The sampling was done after attaining a DO concentration ≥ 2.5mg/L in both reactors at an interval of 12hrs up to a contact time of 72 hrs. The parameters such as COD, BOD_5, Ortho-phosphate and NH_3-N were analyzed for these samples (Standard methods, 20th Edition,1998).

Results and discussions:

The initial typical characteristics of institutional hostel wastewater are depicted in Table 3.

Table 3. Initial characteristics of Institutional boy's hostel wastewater (sewage)

Characteristics	Average value
pH	7.2
COD, mg/L	816
BOD_5, mg/L	479.7
SS, mg/L	4000
Ortho-Phosphate, mg/L	6.52
NH_3-N,mg/L	67.2

In the present study, the performance evaluation of reactor RS-1 and RP-2 at different retention time was carried out for MLSS concentration ranging between 2300 mg/L to 2400 mg/L. Table 4 and 5 shows the results of iteration carried in reactor RS-1, RP-2 for COD, BOD_5, and NH3-N and Ortho-phosphate removal. Here sampling was done at an interval of 12 hrs for a detention period of 72 hrs. From this experiment, it is clear that the maximum removal efficiency was found at longer residence time such as 72 hrs. It is observed that 69.5% of COD, 74% of BOD_5, 69% of NH3-N and 81% Ortho-phosphate removal efficiency was achieved in RS-1, and removal efficiency of 67% COD, 71% BOD_5, 77.4% NH3-N and 68.2% Ortho-phosphate in RP-2 for retention time of 72hrs. Graphical expression of the performance of two media filters were shown in Fig.2 and 3.

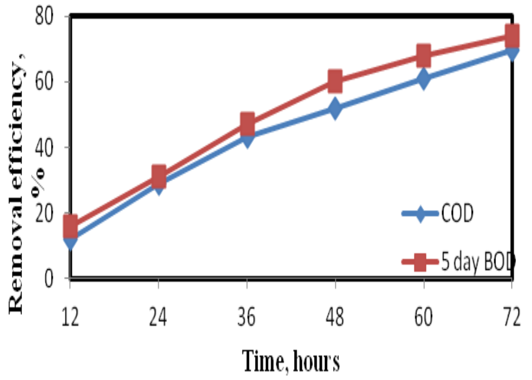

Fig. 2a. Percentage Reduction of COD, BOD_5 in RS-1

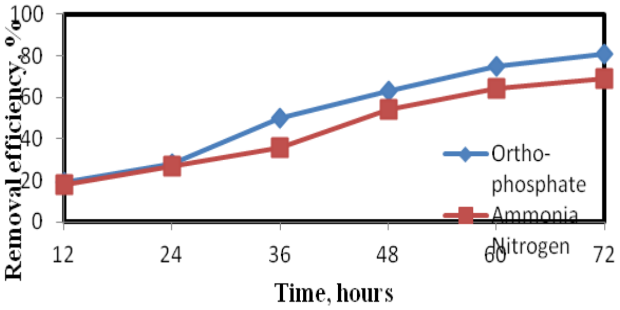

Fig. 2b. Percentage reduction of orthophosphate and NH3-N in RS-1

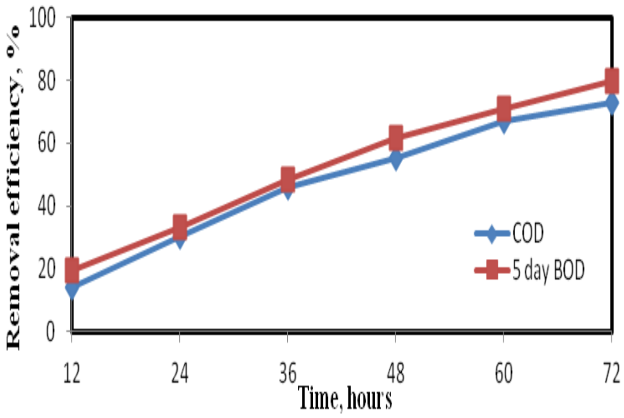

Fig. 3a. Percentage reduction of COD, BOD_5 in RP-2

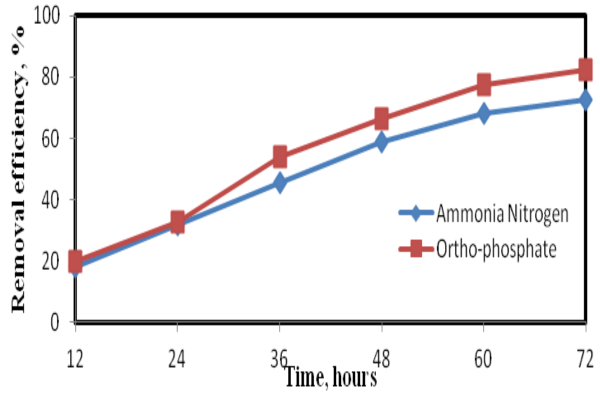

Fig. 3b. Percentage reduction of NH3-N, Ortho-phosphate in RP-2

It is obvious from the results that the degree of removal increases with contact time. This clearly indicates the biofilm growth in the filters with a higher substrate supply. However, with longer contact time the above variation may not be significant. The long-term performance of Sisal and OPEFB fiber reactors depends on their degradation rate and clogging frequency in filters under routine operational conditions.

Table 4. Performance of reactor RS-1

Contact time, hours	Parameters							
	COD		BOD_5		Ortho-phosphate		NH_3-N	
	Concentration (mg/L)	*RE (%)	Concentration (mg/L)	RE (%)	Concentration (mg/L)	RE (%)	Concentration (mg/L)	RE (%)
0	800	-	464	-	6.72	-	61.6	-
12	704	12	389	16	5.43	19.2	50.4	18.2
24	568	29	319	31	4.86	28	44.8	27
36	456	43	244	47	3.37	50	39.2	36
48	384	52	184	60.3	2.51	63	28	54
60	312	61	144	68	1.66	75	22.4	64
72	244	69.5	119	74	1.27	81	19.04	69

*RE=Removal efficiency

Table 5. Performance of reactor RP-2

Contact time, hours	Parameters							
	COD		BOD_5		Ortho-phosphate		NH_3-N	
	Concentration (mg/L)	*RE (%)	Concentration (mg/L)	RE (%)	Concentration (mg/L)	RE (%)	Concentration (mg/L)	RE (%)
0	800	-	464	-	6.72	-	61.6	-
12	688	14	374	19.4	5.38	19.9	50.4	18.2
24	560	30	309	33.4	4.52	32.7	42	31.8
36	432	46	239	48.5	3.08	54.2	33.6	45.5
48	360	55	179	61.4	2.26	66.4	25.2	59
60	264	67	134	71	1.52	77.4	19.6	68.2
72	216	73	94	79.7	1.19	82.3	16.8	72.7

*RE = Removal efficiency

Experiments on continuous process flow regime may yield adequate data on media filters longetivity. But it is confirmed that sisal and OPEFB fibers packed reactors, with well graded packing density may yield consistent and reliable removal of biodegradable matter from wastewater. In the present study, though the sisal and OPEFB fibers facilitate microbial activity, these micro-organisms are expected to depend on substrate from the wastewater for their growth rather than fibrous materials. However, an adaptive shift in substrate dependence should be expected when these reactors are subjected to repeated cycle of closure and re-use.

Conclusions

The following conclusions were made from the present study

- The utility of fibrous materials such as sisal and oil palm empty fruit bunch (OPEFB) fibers as fixed medias for the treatment of wastewater, with a packing density of $50kg/m^{3,}$ has been successfully established in this communication.
- The test reveals maximum percentage reduction of COD (73%), BOD_5 (80%), NH_3-N (73%) and Orthophosphate (82%) with increased retention time in both reactors.
- Instead of conventional medias reported in earlier such as plastics, open cell foam, textiles etc., use of these natural fibrous materials as fixed bed in wastewater treatment equally shows promising removal efficiency of organics and the nutrients.
- This would certainly result in expanding the engineering application for these fibers. The laboratory results obtained from the present study have given necessary information to design and evaluate the long term performance of field scale units.

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