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Performance Evaluation of Fluidized Bed Biofilm Reactor Using Bioball Media for Domestic Wastewater

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Abstract: *This paper presents Bio ball used as carriers for the removal of organics, suspended solids and nutrients from domestic wastewater using Fluidised Bed Biofilm Reactor (FBBR).The performance of FBBR in treating domestic wastewater with respect to operational parameters such as percent filling and HRT. The study was carried out, by optimizing the percent filling of 10%, 20% and 30% to the reactor volume at HRT 3hour, 4hour and 5hour. The operation of the reactor was operated in a continuous mode. Samples were collected at regular intervals and test for removal efficiency of pollutants was obtained. Monitoring the results of the media, it was found that 20% of Bioball filling rate at 5hr was more effective. Classical nitrification and denitrification and the typical enhanced biological phosphorus removal process were achieved in the reactor with 20% bioball filling rate at 5hr, which was operated with a volumetric organic loading of 0.84gCOD/L/d. The removal efficiencies for BOD, COD, TSS, total nitrogen and total phosphorus were found to be 93%, 85%, 75%, 58% and 78% respectively. Bioball media removal efficiency was a practical and cost-effective and a carrier for organics, suspended solids and nutrients removal in domestic wastewater.*

1.Introduction

The problem of sewage disposal and waste management has become increasingly critical due to the increase of worldwide population. Catastrophic impacts on human health and on the environment could result if pollution of receiving waters is allowed to continue. Therefore to preserve water quality for future generations, an effective means of solving this problem must be developed. Wastewater treatment technology has been improving and currently it is possible to treat wastewater to a highly usable level efficiently and in a cost effective way. Domestic wastewater is also one of the major points of pollution sources, which is discharged from residential and commercial areas into the rivers without any treatment. There are many ways to treat domestic wastewater so that it can be reused. The various methods must be safe from a health point of view and not harmful to the environment.

2. Materials and Methods

2.1 Carrier Material

Designed to provide a greater surface area and which are impossible to clog. Media provides even aeration since their large gabs allow air or oxygen rich water to enter. These are commonly used in aquarium filtration. The properties of bio ball are listed below in Table1.

"Table 1. Properties of bio ball"

Properties	Value
Height	1.5cm
Diameter	2.5cm
Material	HDPE
Density	0.96 gm/cm^3

"Fig 1 Bio ball"

2.2 Fabrication and setup of reactor

The laboratory scale Fluidised Bed Biofilm Reactor was fabricated with dimensions arrived based on the literature and standards. The reactor is a circular column made up of acrylic material of total volume 3.5litre. The reactor is 45cm in height and has an outer diameter of 11cm and inner diameter of 10cm and 5mm thick. The dimensions of the reactor are tabulated in Table 2. At the top an inlet was provided using a feed tank of 10litre capacity which was fitted with pump to supply influent to the reactor. An outlet for effluent was provided at the bottom of the reactor.

“Table 2. The dimensions of the reactor”

S.no.	Reactor Dimensions	Value
1	Outer diameter	11cm
2	Inner diameter	10cm
3	Height	45cm
4	Thickness	5mm
5	Working volume	3.5litre

2.3 Experimental Methodology

First the reactor was set up as designed reviewing the literatures. At the mean time the collected domestic wastewater sample was characterized and acclimatization of sludge was done followed by optimization studies which were HRT and percent filling of biocarriers. Finally analysis of the biologically treated domestic wastewater was carried out by appropriate standard methods, thus evaluating the performance of biological treatment process. This study was to find a cost- effective, advantageous an efficient media for greater removal of pollutants in domestic wastewater.

2.4 Seeding and Start up

Before start up, the reactor was filled with media and the contents were allowed to stabilize at the required temperature. The reactor was inoculated with required quantity of fresh collected sludge from aeration tank of Anna University STP. The use of heavy seed sludge may result in wash out of the media due to decrease in the bulk density and the media leaving may block the column. Thus the digested supernatant was used for the starting of the reactor instead of using heavy seed sludge. The sludge was added in calculated amounts to bring the required MLSS concentration for the treatment process.

2.5 Biological treatment of domestic wastewater in FBBR

The experiment was conducted at various HRT and percent filling of biocarriers. The reactor was operated at continuous mode. The treatment process in the reactor was started after the acclimatization process. The effluent from the feed tank was pumped using peristaltic pump. Diffusers and air pump was used, in order to provide proper circulation of biocarrier and for microbial growth. The air flow rate was varied between 3lpm to 9lpm.The flow rate was increased slowly. During treatment process, the microorganisms got attached to biocarriers and formed a thin film called biofilm. The nutrients and oxygen diffused through the biofilm and also the biodegradation took place. The pH of effluent was maintained in the range of 6.5-7.5 for sufficient growth of microorganism. The biodegradation of organic matter was tested by analysing the sample. Finally the treated water was allowed for sludge settlement. The removal efficiency of the reactor was found from the COD, BOD, TSS, Phosphates and Total nitrogen tests by standard methods.

2.6 Operational parameters

The efficiency of organics, suspended solids and nutrients removal in the reactor was studied by optimizing the operating parameters such as percent filling of biocarrier to the reactor volume and HRT.

“Table 3.Operational parameters”

Flow rate(L/hr)	HRT(hr)	OLR(kg/m^3.d)
1.16	3	3.99
0.875	4	3
0.7	5	2.4

2.7 Optimization of percent filling of biocarriers

The purpose for this study was to determine the optimum percent filling of biocarriers that was most effective and efficient in aiding the treatment of domestic wastewater. The percent filling was calculated and obtained by reviewing literatures.

2.8 Percent filling of biocarriers to reactor volume

Biocarriers was also a factor that influenced the rate of biodegradation. The bed here was fluidized hence the biocarriers was filled accordingly to make it act as a fluidised particle. The percentage filling of biocarriers is defined as the volume of carrier material which includes voids to the reactor working volume. The volume of carrier material in litres and number of pieces required for percent filling was calculated as below and the values are presented in Table 4.

Percentage filling =

$$\frac{\text{Volume of biocarrier including voids (Litre)}}{\text{Reactor working volume (Litre)}} \times 100$$

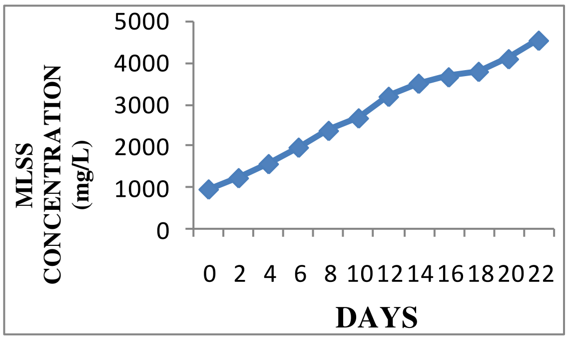
"Table 4. Percent filling of biocarriers to reactor volume"

S.no	% Filling of biocarriers	Volume of biocarrier (L)	Depth (cm)
1.	10	0.35	4.5
2.	20	0.7	9
3.	30	1.05	13.5

2.9 Acclimatization process

Before start up, acclimatization was started by innoculating 3L of fresh collected sludge taken from STP, Anna University in the reactor. The reactor was filled with media and the contents were allowed to stabilize at the required temperature. Its contents were aerated continuously at 9lpm using three air pumps. The nutrients were added in calculated amounts regularly.

The sludge was replaced by raw domestic wastewater in calculated quantity to bring in the required MLSS concentration to start the treatment process. MLSS was regularly tested at an interval of two days. The concentration of active biomass in the FBBR system reported is in the range of 3200mg/L to 4500mg/L for domestic wastewater. (Feng Quan, 2012). As MLSS concentration reaches accordingly, it is observed that microorganisms have attached to the media. As 4570mg/L MLSS concentration was reached, the biological treatment was started.



"Fig 2. Mixed Liquor Suspended Solids concentration of acclimatization process"

3. Results and Discussion

3.1 Characterization of collected domestic wastewater sample

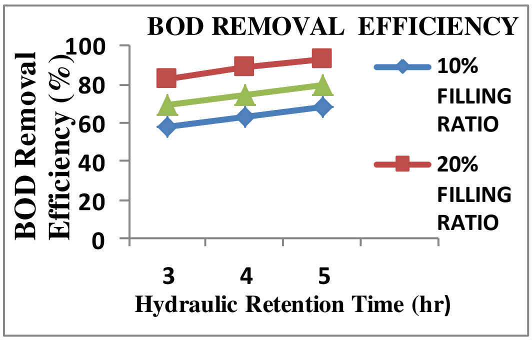
Samples were collected for initial characterization of domestic wastewater from Anna University STP .The collected domestic wastewater was analyzed for the parameters pH, TSS, BOD_3, Alkalinity, COD, Nitrogen, Total Phosphates and Total Nitrogen and the results found are tabulated in Table 5.

"Table 5. Characteristics of collected domestic wastewater sample"

Parameter	Value
pH	6.6
Total Phosphate (mg/L)	6.5
COD (mg/L)	445
BOD_3 (mg/L)	285
TSS (mg/L)	316
TDS (mg/L)	725
TOC (mg/L)	83
TN (mg/L)	37
TKN (mg/L)	39

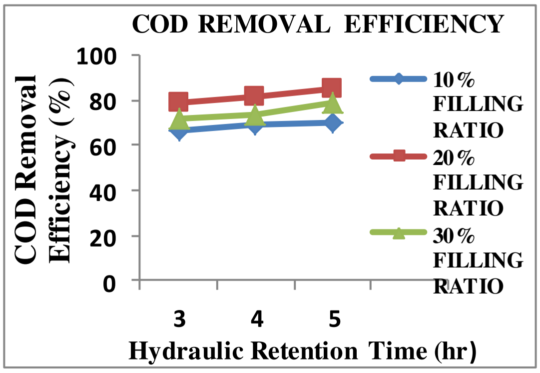
3.2 Effect of bioball media for removal of organics in FBBR

The reactor was operated with an organic loading rate of 2.4–3.99kg/m^3.d. With COD values in the effluent ranging between 520-525mg/L, it proved possible to achieve 67-85% removal of organic compounds. In other studies, (Masłon´ and Tomaszek ,2011) obtained COD in effluent in the range 4.8–36.8 mg O_2/L at OLR levels in the range 0.432–0.972gCOD/L/d. Removal of organic compounds occurred in all phases of operation of the FBBR. The highest COD consumption was noted for simultaneous phosphate release and denitrification. Simultaneous processes of mineralization and oxidation of organic compounds occurred intensively in the final period of the experiment (J.M. Poyatos, 2012).



"Fig 3. Effect of BOD removal efficiency by Bioball media"

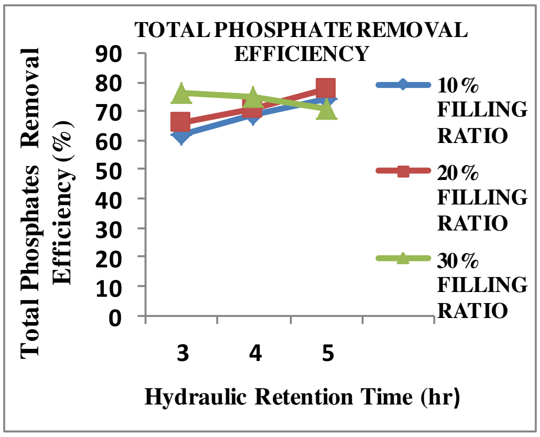
The results indicated that the average COD and BOD removal efficiency at 10%, 20% and 30% carrier filling rates were 69%, 82%, 75% and 63%, 68% and 79%. Although removal efficiencies were more at all the carrier filling rates, fluctuations in the trend of removal efficiency at 10%, and 30% carrier filling rates resulted in occurrence of an unstable condition. In comparison, average removal efficiency of 20% carrier filling rate was found to be higher and steadier which may be as a result of an active biofilm layer presence on the carriers surface (Hontoria, 2014). However adding higher amount of carriers that is 40%, 50%, etc into the reactor led to a decrease in removal efficiency which might be due to the accumulation of biomass on carriers surface.



"Fig 4. Effect of COD removal efficiency by Bioball media"

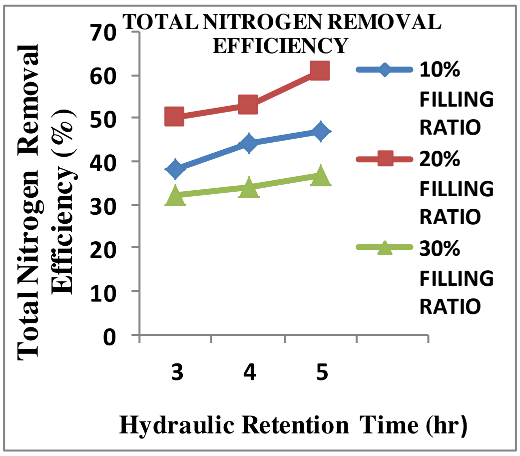
3.3 Effect of bioball media for removal of nutrients in FBBR

Total Phosphate and Total Nitrogen removal efficiencies at 3h, 4h, and 5h with flow rate of 1.33L/hr, 1L/hr, 0.8L/hr and. The removal efficiency decreased significantly with increasing the amount of carriers in the reactor. Initially efficiency was at the peak due to the microbial growth by phosphate consumption.



"Fig 5. Effect of Total Phosphate removal efficiency by Bioball media"

On the other hand, there was a decrease in phosphate consumption as more carriers were added to the reactor. This might be due to the competition for enough oxygen and space which occurs between heterotrophs and nitrifiers.



"Fig 6. Effect of Total Nitrogen removal efficiency by Bioball media"

3.4 Effect of bioball media for removal of TSS in FBBR

As biofilms grow on the FBBR carriers there is a continuous detachment of biomass caused by abrasion, caused by carriers colliding and scraping against each other, erosion caused by shear forces in the bulk liquid surrounding the biofilm, sloughing, where larger biofilm segments detach from the carrier element, and predator grazing (Morgenroth & Wilderer, 2010).

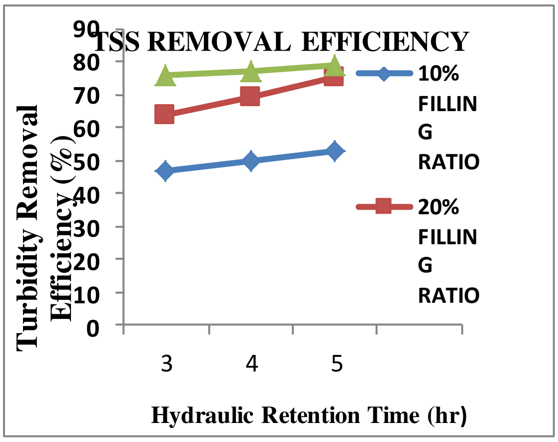
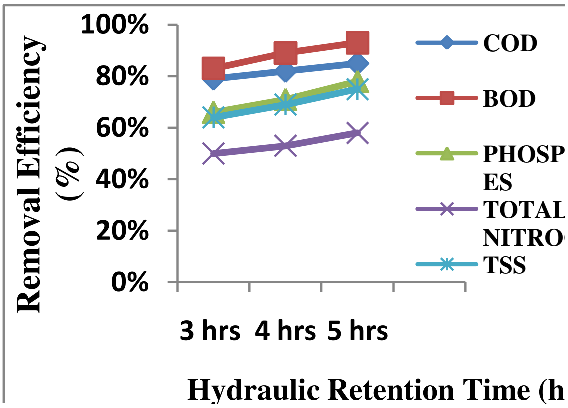


Fig 7. Effect of TSS removal efficiency by Bioball media

While abrasion and erosion result in a continuous detachment of smaller particles from the biofilm surface, sloughing may occur randomly and result in the detachment of whole biofilm segments from the carrier surface (Horn et al., 2009).

Simultaneously, predator grazing may affect the overall sludge production of the FBBR process, as predating consume bacteria in the system (Lee & Welander, 2012). Thus suspended solids increased as the HRT and filling rate of carrier increased.

The optimization result showed a high rate of overall removal efficiency in 20% carrier filling of bioball at 5hrs HRT.



"Fig 8. Overall removal efficiency by 20% of Bioball media"

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