A Study on Biological Treatment of Bio-Diesel Industrial Effluent Using FBBR

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Abstract:
The present study involves experimentation on the treatment of bio-diesel industrial effluent using a laboratory scale model of Fluidized Bed Bioreactor (FBBR) with three different bed materials viz., MBBR Plastic media, Pumice Stones, high density Foam material. The experiment mainly focuses on the removal of Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) from the bio-diesel industrial effluent. The experiment is conducted for a period over 2 to 3 weeks at daily intervals, till the reactor gets stabilized and a maximum and uniform rates of percent removal of BOD and COD are obtained. The experimental data is analyzed and the results are presented in suitable formats. From the Bio-kinetic study involving reaction rate kinetics and microbial growth kinetics it is observed that, the bio-kinetic reactions taking place in the reactor conform to First order rate of reactions and the Foam pieces are proved to be a good alternative material when compared with that of the Commercially available MBBR (plastic) media.

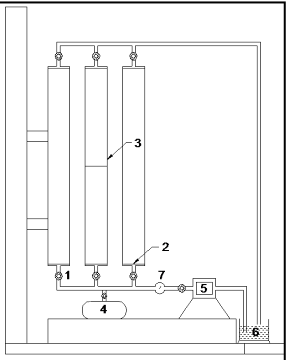
Keywords: *Bed material, Biological Oxygen Demand (BOD), Bio-diesel, Chemical Oxygen Demand (COD), Fluidized Bed Bio Reactors (FBBR), Microbial Growth Kinetics, Reaction rate kinetics.*

I. Introduction

Biodiesel is a domestically produced renewable fuel that can be manufactured from vegetable oils, animal fats or recycled organic materials like greases etc. Most biodiesel manufacturing processes result in the generation of process effluents with free fatty acids and glycerin. Other constituents in the biodiesel industrial effluent include organic residues such as esters, soaps, inorganic acids and salts, traces of methanol etc. The typical biodiesel manufacturing process effluent has high concentrations of BOD, COD, TSS, oil and grease etc. The present work focuses on the removal of BOD and COD from the effluents generated in the bio-diesel industry using a laboratory scale Fluidized Bed Bioreactor (FBBR). Earlier works on FBBR have reported good removal of organic wastes[1,2] and a good number of empirical as well as rational parameters based on biological kinetic equations can be used in the design of biological wastewater treatment processes like FBBR [3]. These Bio-kinetic coefficients include specific growth rate (μ), maximum rate of substrate utilization per unit mass of microorganisms (k), half velocity constant (k_s), maximum cell yield (Y) and endogenous decay coefficient (k_d) and to be used in the design of bio-reactors [4]

II. Experimental Setup

The experimental system consists of three Acrylic glass columns of 120 cm length and 6.9 cm dia each arranged parallel to each other, with valves at the top and bottom of the columns to regulate the flow through them, as shown in Fig.1. The columns are filled with different bed materials viz., Commercially available MBBR (Plastic) media, Pumice stones and high density Foam pieces. A mesh is provided between the flanges so as to prevent the loss of bed material into the pipe. A flow meter is arranged on inlet pipe to measure rate of flow. Compressed air is supplied to the fluidizing column so as to make sure that the bed gets fluidized. About 15 liters of effluent sample from a local bio-diesel industry (Atchutapuram, Visakhapatnam) is collected each day and diluted to 1:5 concentrations and is used as stock solution for experimentation. A concentrated biomass solution is prepared using tomato slurry mixed with the wet sludge collected from domestic sewage plant, in aerobic conditions. The process is continued for a week and the slurry obtained at the end is introduced into the experimental columns to act as seed for biomass acclimatization on bed particles in the columns.



1. Vlave 2.Stainless Steel Mesh
3. Acrylic Glass Columns 120 cm long
4.Air Compressor 5. 0.5 HP Motor
6. Stock Solution 7.Flow meter

Fig.1 Experimental Setup

III. Methodology

The acclimatized biomass is transferred to the experimental columns and the columns are filled with water for three days before the start of experiment, and then the experiment is carried out by pumping the effluent taken from the local bio-diesel industry. The initial values of BOD and COD are determined. The samples from outlet of the experimental columns are collected at intervals of 30min, 60min, 90 min and the respective BOD and COD values are determined. The same experiment is carried out with different bed materials. The process is continued till the constant percentage removals of BOD and COD are obtained.

The reaction rate coefficients are determined using the experimental results obtained using the method of integration which involves the substitution of the measured data of the amount of reactant remaining at various times into the integrated form of the rate expression. Zero, First and Second order reaction expressions are used to find the Reaction rate coefficients. The microbial decay coefficients are calculated using the specific substrate utilization rate (U) and the specific growth rate (μ).

IV. Results and Discussions

The percentage removals of BOD and COD at different operation times using MBBR Media (Plastic), Pumice Stones and Foam Pieces as bed materials are as shown in Fig 2 to 7.

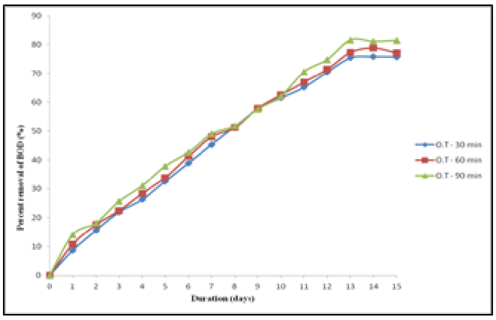


Fig.2 Percentage removal of BOD using MBBR Media(Plastic)

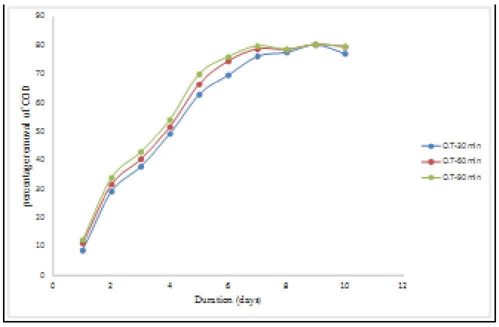


Fig.5 Percentage removal of COD using MBBR Media(Plastic)

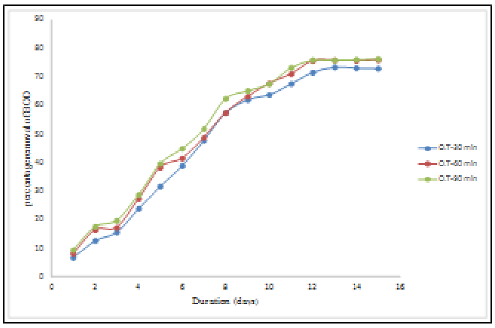


Fig.3 Percentage removal of BOD using Pumice Stones

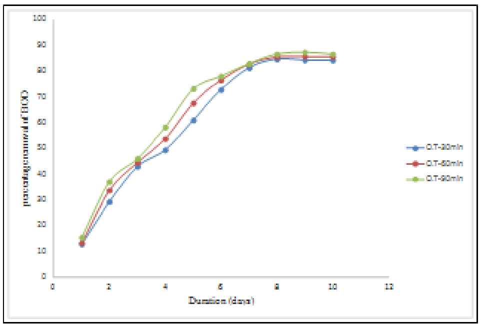


Fig.6 Percentage removal of COD using Pumice stones

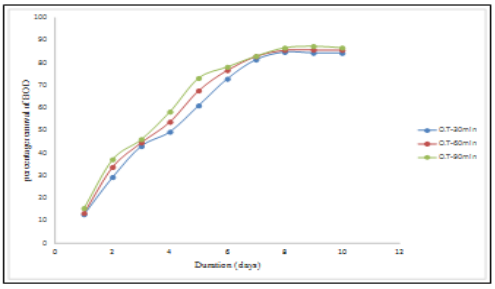


Fig.4 Percentage removal of BOD using Foam Pieces

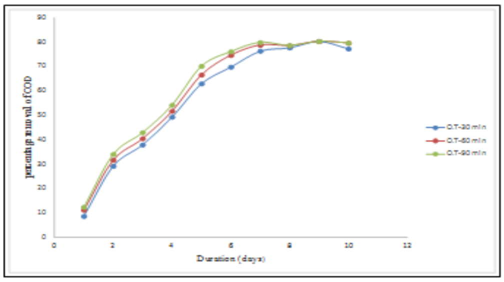


Fig.7 Percentage removal of COD using Foam Pieces

It is observed that the maximum percentage removal for BOD is found to be 87.39%, 83.32%,76.38%, for the bed materials Foam pieces, Commercially available MBBR media(Plastic), Pumice stones respectively, at an operation time of 90 minutes. Similarly the maximum percentage removals of COD are found to be 80.39%, 73.32%, 65.38%, respectively, for the bed materials in the same order respectively. The experimental duration/the acclimatization period is found to be 10, 14, and 15 days against the bed materials Foam pieces, Commercially available MBBR media (Plastic), Pumice stones respectively. From these results it is observed that, Foam is found to be a good alternative for the Commercially available MBBR (plastic) media.

V. Reaction Rate and Microbial Growth Coefficients

For the study on Reaction Rate Coefficients, three different reaction rate models are taken into consideration viz., Zero order, First order and Second order reaction. Plots of the integrated forms of the reaction rate expressions are used to determine the reaction rate coefficients ‘k’. The experimental programme conforms to first order reaction rate kinetics. The first order reaction rate coefficients (k) obtained for the experiments with three different bed materials ranged from 0.07day^{-1} to 0.23day^{-1} at different operation times. First order kinetics for the removal of BOD and COD for the three bed materials at the operation time of 90 min are shown in Fig 8 to 13. These are in agreement with the earlier experimental works [5, 6, 7] referred. At the same time, these coefficients are found to be more for the experiment with Foam Pieces as bed material.

The microbial decay coefficients (k_d) are obtained using the specific growth rates (μ) and specific substrate utilization rates (U), as presented in Table 1. It is observed that, the microbial decay coefficient (k_d) are found to be increasing against the following order of usage of bed materials. i.e., Pumice stones, MBBR media (plastic), and Foam Pieces for different operation times and at the end of the acclimatization period. Maximum microbial decay coefficient ‘k_d’ values are obtained when Foam Pieces are used as bed material when compared to Pumice stones and MBBR media (plastic). The Microbial decay coefficients obtained in the study are well in agreement with earlier works [8,9].

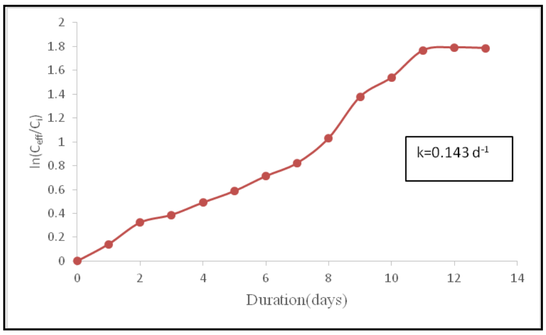


Fig.8 First order kinetics for the removal of BOD (Bed material: MBBR media)

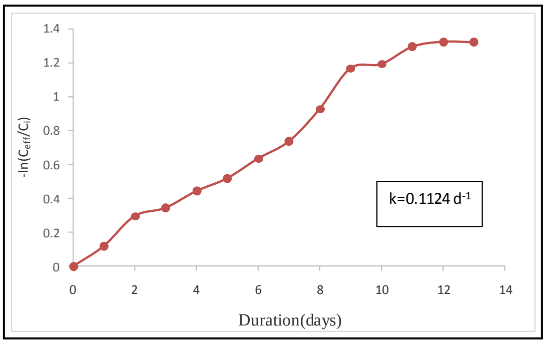


Fig.11 First order kinetics for the removal of COD (Bed material: MBBR media)

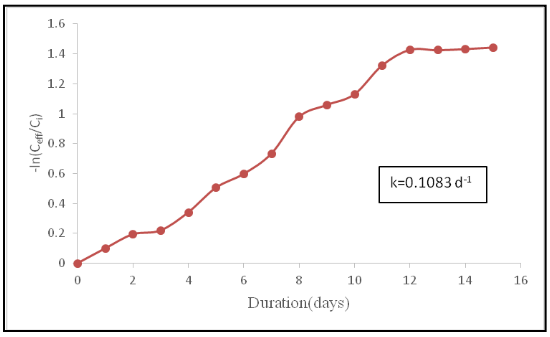


Fig.9 First order kinetics for the removal of BOD (Bed material: Pumice Stones)

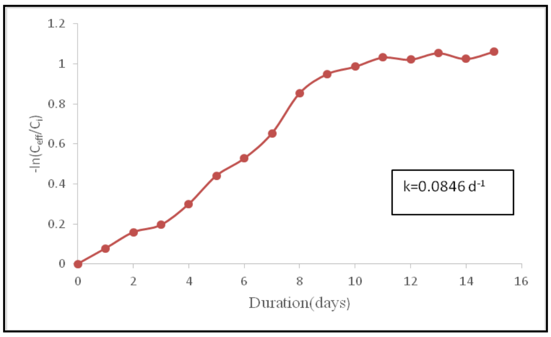


Fig.12 First order kinetics for the removal of COD (Bed material: Pumice Stones)

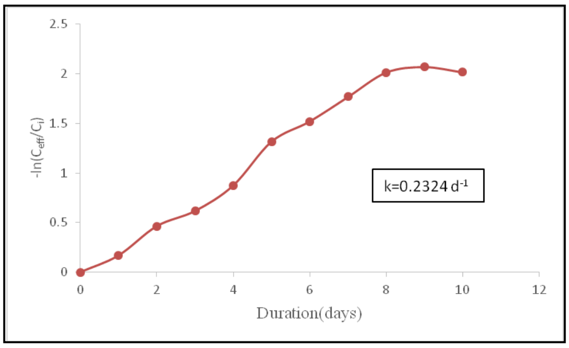


Fig.10 First order kinetics for the removal of BOD (Bed material: Foam pieces)

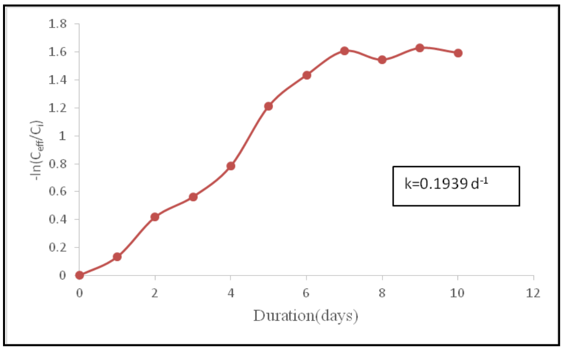


Fig.13 First order kinetics for the removal of COD (Bed material: Foam pieces).

Table 1 The Microbial Decay Coefficients (k_d)

S.No	Bed material	Operation time (minutes)	Microbial Decay Coefficient (kd), day-1 For BOD
1	Bio carriers (Plastic)	30	0.003
		60	0.0034
		90	0.0037
2	Pumice stones	30	0.003
		60	0.002
		90	0.003
3	Foam	30	0.005
		60	0.004
		90	0.004

VI. Conclusions

1) The FBBR has acclimatized in 10, 14 and 15 days against the usage of bed material viz., Foam pieces, Commercially available MBBR media(Plastic), Pumice stones respectively.
2) The maximum percent removal of BOD and COD are found to be more in the experiments conducted with Foam Pieces as bed material.
3) The reaction rate kinetics of the experimental programme conform to first order reaction rate kinetics and the reaction rate coefficients (k) obtained are in agreement with the earlier works.
4) The microbial decay coefficient (k_d) are found to be increasing against the following order of bed materials. i.e., Pumice stones, MBBR media (plastic) and Foam Pieces for different operation times and at the end of the acclimatization period.
5) Therefore, it can be concluded that, Foam Pieces can be used as a better alternative against the Commercially available MBBR media (plastic) for the removal of both BOD and COD in FBBRs.

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