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Biosorption Studies and Kinetics on Textile Effluent Treatment Using Packed Bed Reactor

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Abstract

The utilization of *Aspergillus niger* biomass for the treatment of effluent collected from the dying units provides an insight into the potential of fungal biomass in treatment of textile effluent. The decolorization capability of the biomass was observed under shake flask studies using UV spectrophotometry and packed bed column studies were carried out for analyzing biosorption efficacy in a pilot scale. The process parameters maintained were, retention time varying from 80 to 26 min, flow rate from 2 ml/min to 6 ml/min and porosity of the column as 0.425. The dye decolorization by the fungal biomass and the metal adsorption was found to be maximum at 2 ml/min of flow rate and 80 minutes of retention time. The adsorption isotherms Langmuir and Freundlich were evaluated for the significance of the adsorption process. Specific metal uptake rate of the biomass has been studied to identify the rate of metal uptake by the biomass.

Keywords: Biomass; Effluents; Isotherms; Biosorption

Introduction

Effluent is wastewater - treated or untreated - that flows out of a treatment plant, sewer, or industrial outfall. Chemical methods involve the usage of oxidation, electrolysis and ozonation these methods can efficiently remove mainly sulphur and disperse dyes, whereas acid, direct, reactive and vat dyes are presented in very low coagulation-flocculation capacity [1]. Dye industry effluent causes one of the major environmental problems due to its removal of colors from the effluent prior to discharge of local sewage treatment. Bright colored water soluble dyes are problematic [2]. Dyes, currently used can be degraded or removed with physical and chemical processes and sometimes the degradation products are more toxic [3]. Several combined aerobic and anaerobic microbial process, using adapted mixed populations are believed to enhance the degradation of dyes [4]. Though, lot of works on dye effluent using physico-chemical method have been carried out [5,6] very little work on the degradation of dye using biological organisms are available. The predominance of heavy metal concentration can be found in the textile industry effluent due to extensive use of chemical colorants and the formation of organic compounds when discharged into water bodies they have a large effect on the water bodies by making them unsuitable for human activities where heavy metals have been found in larger quantities [7]. Chromium in specific is found predominantly in the textile effluent and requires removal of Chromium metal from suspended effluents. Biological methods of metals removal from aqueous solution, known as biosorption, have been recommended as cheaper and more effective technique. Fungal systems appear to be the most appropriate in the treatment of colored and metallic effluents [8]. The earlier works conceded suggest the utilization of fungal biomass for treatment of dye effluents and heavy metals and its potential application in a batch process. *Aspergillusniger*being a versatile mat forming fungus can be utilized for the derivation of fungal mat from the organism. The major onset of the work details utilization of fungal biomass in a pilot scale reactor setup through which the effective removal of dyes and heavy metal is to be analysed. The work deals with the utilization of *Aspergillusniger* fungal biomass in effectively treating the unprocessed effluent.

Materials and Methods

Effluent collection and characterization

The effluent samples for the biosorption process were collected from a dyeing unit in Erode, Tamil Nadu, India. The samples were directly collected from the outlet before it was subjected for further treatment. The effluent was prepared in various concentrations and scanned between ranges from 900 nm to 300 nm using UV spectrophotometry. The peak values obtained on various concentrations were analyzed and the reference peak was found to be 540 nm (Table 1).

S.No.	Constituents	Untreated effluent
1	Color intensity of effluent	340 hazen
2	Density	1.0075 g/cc
3	Total dissolved solids	6212 mg/l
4	Chromium VI	4297 ppm
5	BOD	641 ppm
6	COD	3360 ppm
7	pH	8.5

Table 1: Characterization of effluent

Microorganism selection

The microorganism used for biosorption study was Aspergillus niger (MTCC NO 281) which was initially cultured in PDA (Potato Dextrose Agar) media. The fungus was grown as suspension culture to obtain fungal mat.

Fungal mat preparation

The suspension culture was autoclaved and the mat was separated by filtration process. The mat obtained was washed with ample amount of distill water and pretreatment was carried out using 0.2 N NaOH and boiled for 15 min. The alkali treated mat was cleansed with distill water and dried in a hot air oven. The dried biomass was powdered using a mortar and pestle and stored for biosorption studies.

Batch analysis of biomass efficacy

The effluent samples were diluted and the concentration of the samples was maintained at 1%(V/V). 0.50 mg of the powdered biomass was added to the effluent to analyze the biosorption capacity of fungal biomass. The samples were kept in rotary shaker and the experiments were carried out for a period of 15 days for the observing of dye decolorization.

Packed bed column

Coir pith and fungal biomass were alternatively packed as a bed in the column for biosorption studies. Coir pith was mainly used as a supporting medium for the biomass. The column studies were carried out until saturation of the packed bed and the data obtained were analyzed using suitable adsorption isotherms to understand the efficiency of the fugal biomass for effluent treatment.

Results and Discussions

Initial analysis of dye decolorization

The initial analysis of biosorption which was carried out in shake flask showed that *Aspergillus niger* fungal biomass was effective in the adsorption of dyes present in the effluent. The process of decolorization was analyzed at 540 nm which showed the amount of biosorption of dyes. The rate of decolorization of samples was analyzed at every 48 hrs and a maximum decolorization of 83.56% was observed at 336 hrs (Table 2).

Time	Dilution	Percentage of decolorization
0	10	0
48	10	17.36
96	10	30.85
144	10	38.25
192	10	59.14
240	10	64.78
288	10	76.89
336	10	83.56

Table 2: Decolorization of dyes in batch process

Packed bed column analysis

The packed bed system was designed for the Decolorization and metal removal from the effluent. The studies using packed bed column was based on the parameters used for large scale effluent treatment process. The flow rate was maintained from 2 ml/min to 6 ml/min and porosity of the column was maintained at 0.425. The dye decolorization and Cr (S- Diphenyl carbazide method) biosorption was noted by analyzing samples from each cycle and the values were plotted (Figure 1).

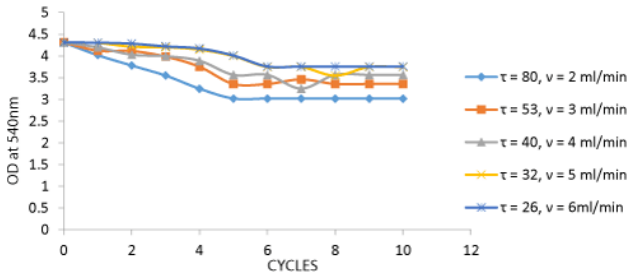

Figure 1: Decolorization dynamics of dye Decolorization in control

The above graph represents data for the rate of decolorization by coir (control). During the process bed saturation was found at 6 cycles at a flow rate of 2 ml/min. The number of cycles for decolorization increased as the flow rate increased. The analysis showed that coir also influences the process of adsorption (Figure 2).

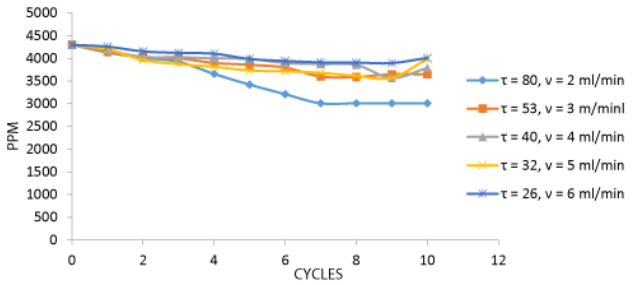

Figure 2: Biosorption profiles of Chromium adsorption in control

The graph above represents data for the rate of biosorption by coir (control). Cr uptake was maximum at 2 ml/min of flow rate at the end of 8 cycles and the efficacy decreased in biosorption of total Cr due to the increase in flow rate (Figure 3).

The Decolorization of dyes and the number of cycles for decolorization at various flow rates are depicted in the graph. The dye decolorization was found to be maximum at a flow rate of 2 ml/min providing maximum retention time for the decolorization process which provides maximum dye Decolorization at 5 cycles and the number of cycles increased due to increase in flow rate (Figure 4). The biosorption of total Cr and number of cycles for biosorption process at various flow rates are depicted in the graph.

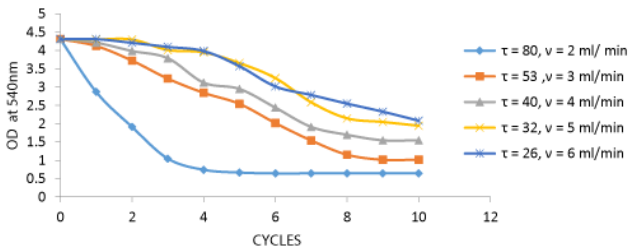

Figure 3: Decolorization dynamics of the effluent by biomass

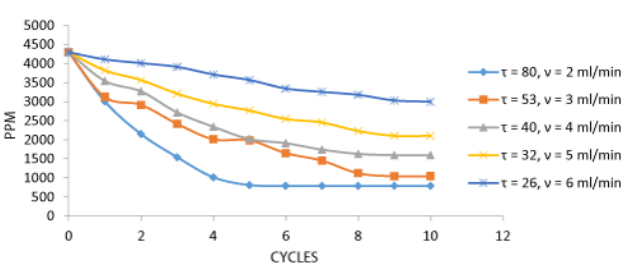

Figure 4: Biosorption profiles of Chromium by biomass

The Cr biosorption was found to be maximum at a flow rate of 2 ml/min and there is a saturation of metal uptake after 6 cycles. The variation in biosorption of Cr is due to the increase in flow rate resulting in the decrease of retention time.

Specific metal uptake rate (Q)

The specific metal uptake rate Q is the rate of metal uptake by the biomass at a particular retention time this determines the specific amount of metal uptake by the biomass at a particular cycle during biosorption (Figure 5).

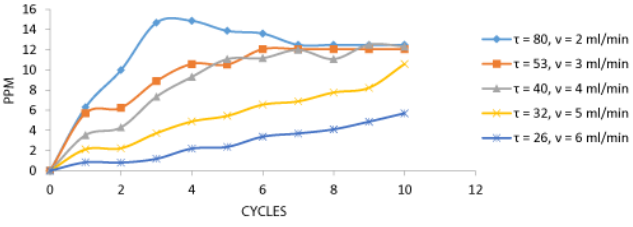

Figure 5: The total metal uptake rate Q for the overall process

The specific metal uptake rate depends on the retention time, and porosity maintained in the process. The specific metal uptake rate was higher at 2 ml/min and decreases with the decrease in retention time. The decrease in biosorption of Cr metal from the effluent was due to the rapid increase of flow rate which affects the time of biosorption in packed bed column.

Langmuir isotherm

Langmuir isotherm was used to define the occurrence of the adsorption process in a monolayer. The isotherm was calculated for the retention time 40 and flow rate 4 ml/min during the biosorption of chromium by the fungal biomass (Figure 6).

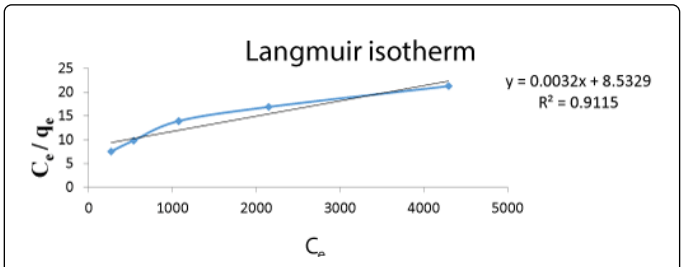

Figure 6: Langmuir isotherm

The Langmuir isotherm was analysed and showed the process of Cr biosorption occurred in a monolayer. The Q_{max} value was obtained from the process showing that the interaction between the sorbent and the sorbate at 4 ml/min of flow rate was 8.5329. The R^2 value 0.9115 shows the isotherm model fits to the reaction.

Freundnlich isotherm

The Freundlich isotherm was used to determine degree of non-linearity of the process and to determine heterogeneity of the system in which the reaction occurs. The isotherm was calculated for the retention time 40 and flow rate 4 ml/min during the biosorption of chromium by the fungal biomass (Figure 7).

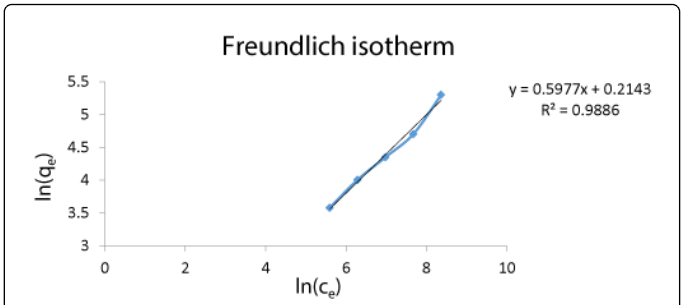

Figure 7: Freundlich isotherm

Freundlich isotherm was analyzed for the determination of heterogeneity of the process and to determine degree of non-linearity. The process of Cr biosorption was nonlinear. The R^2 value 0.9886 shows the isotherm model for the pilot scale process thus depicting the overall process to be non-linear. The Langmuir isotherm and the Freundlich isotherm have a significant fit and shows that the interaction between the biomass and Cr occurs at a more effective rate.

Efficacy of packed bed column

The amount of dye Decolorization and Cr metal biosorption was determined by analyzing the values of sample collected after each cycle from the packed bed column (Figure 8). The characterization of effluent samples treated in packed bed column showed decrease from the initial values (Table 3).

S.No.	Constituents	Untreated effluent	Treated effluent
1	Color intensity of effluent	340 hazen	186 hazen
2	Density	1.0075 g/cc	0.9982 g/cc
3	Total dissolved solids	6212 mg/l	1904 mg/l
4	Chromium VI	4297 ppm	790 ppm
5	BOD	641 ppm	53 ppm
6	COD	3360 ppm	200 ppm

Table 3: Analysis of treated effluent

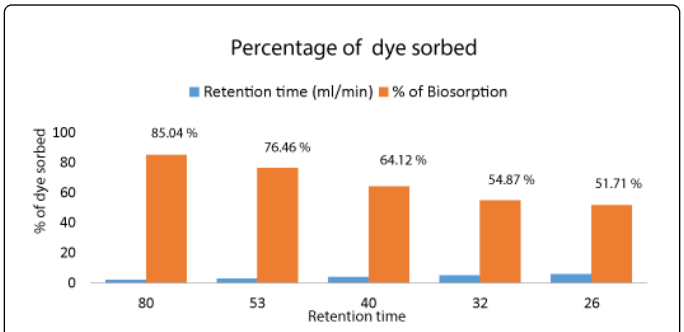

Figure 8: Dye decolorization by the biomass

The dye decolorization by *Aspergillus niger* biomass was analyzed from samples collected after each cycle. The results show that maximum of 85.01% of the effluent was decolorized at 80 minutes of retention time in the column. There is a gradual decrease in the decolorization as retention time decreases due to increased flow rate. This shows that flow rate plays an important role in the biosorption process (Figure 9).

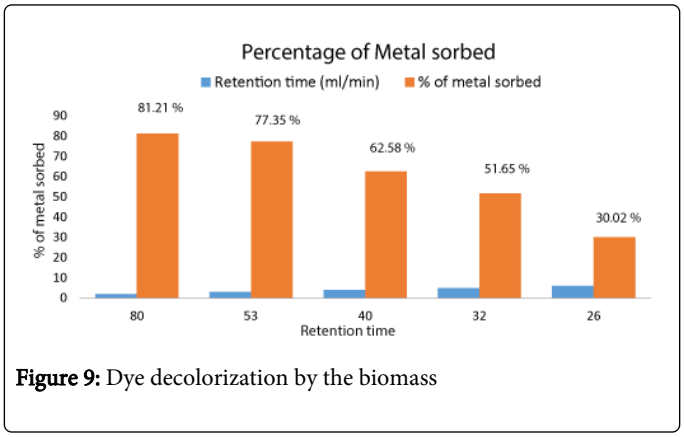

Figure 9: Dye decolorization by the biomass

The Cr metal biosorption by *Aspergillus niger* biomass was analyzed from the collected samples after each cycle. 81.21% of Cr metal was biosorbed by treating of effluent in the packed bed column which was maximum during 2 ml/min of flow rate. The efficiency of the metal removal depended on retention time. The higher the retention time of effluent in the column the higher is the metal biosorption.

Discussions

The overall study revealed that *Aspergillus niger* biomass can be effectively used for effluent treatment process. Chromium was found to be abundant in the effluent. *Aspergillus niger* being an versatile fungus which proliferates and forms mat in large quantities. The culturing of fungus is simpler and yield of biomass from the culture is higher. The *Aspergillus niger* biomass efficacy was initially analysed under batch shake flask condition to determine the biosorption capacity of dye decolorization and Cr metal biosorption by the biomass. The batch study shows that *Aspergillus niger* biomass was capable of decolorizing 83.56% of the dyes and was potentially an effective biomass for the utilization in packed bed studies. The packed bed column consists of coir pith and fungal biomass which was packed in layers for the biosorption process. The finely powdered biomass acted as the sorbent in the process of biosorption while coir which was an adsorbent improved the adsorption efficiency and as a supporting material for the biomass. The effluent was passed through the column in cycles and efficacy of the column was analyzed from the samples collected at each cycle. The analysis revealed that at 2 ml/min of flow rate and retention time of the effluent being 80 minutes gave a maximum dye decolorization at 5 cycles. The variation and increase in cycles was noted as flow rate increased, the increase in flow rate led to decrease in retention time which increased the number of cycles required for decolorization process. The metal biosorption was found to be maximum at 80 minutes of retention time and flow rate of 2 ml/min which was completed at the end of 6 cycles. The increase in flow rate resulted in the increased number of cycles and a decrease in retention time. The data obtained from the packed bed studies were analyzed using Langmuir and Freundlich isotherms to determine the efficacy and nature of the process. The Langmuir isotherm was calculated for 40 minutes of retention time and 4ml/min of flow rate so as to determine Q_{max} of an intermediate process in the packed bed studies. The Langmuir isotherm was fit to the flow rate with a R^2 value of 0.9112 and a Q_{max} value of 8.5329 which was the maximum amount of sorbent concentration adsorbed by the sorbate. The Freundlich isotherm was used to test the heterogeneity of the process and the degree of nonlinearity. The process in packed bed should not be linear as bed saturation occurs earlier and efficacy of the packing is reduced substantially. The isotherm was used to determine the process at 4ml/min of flow rate and 40 minutes of retention time which showed that the process is nonlinear and the R^2 value obtained was 0.9886. The overall packed bed study revealed that 85.04% of the effluent was decolorized and Cr biosorption was 81.21% of the total chromium present. The specific metal uptake rate of Cr by the biomass at various flow rates was analyzed. The effluent had enormous reduction in BOD, COD, density and TDS which was noted after treatment in packed bed column showing the efficacy of biomass in treating the various constituents of the effluent.

Conclusion

The study provides an intense insight in the process of effluent treatment by the utilization of fungal biomass. The usage of biomass for the treatment of textile effluents have been massively reported but the effective utilization of the fungal biomass has been successfully implemented in the present study. The reactor studies using the column packed with fungal biomass and coir has shown a significant result with higher efficiency in treating textile effluent which is harsher and more toxic than the synthetic effluents prepared in laboratories. Since it is an economically feasible process, it can be effortlessly

commercialized based on the requirements of the textile unit and can be implemented for the urban areas which will be a breakthrough for effluent treatment complications. This process eases the toxicity of the effluent in all the parameters providing a commendable accomplishment for total effluent treatment. In the current scenario the search for affordable and efficient technology for treating the effluent holds a key in determining the cost-benefit strategies in industrial sectors and this present study using fungal biomass for the effluent treatment will be a prodigious boon for the textile industries if commercialized and utilized.

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