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Biosorption Study of Congo-Red on Dried Mixed Microbial Biomass

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Abstract — *Dyes are toxic water pollutants generally present in the effluents of textile industries. Congo red (CR) was chosen as a dye model. A high level of worldwide production and extensive use of dyes generate substantial volumes of coloured wastewaters. The present work aims to investigate the removal of dye Congo red from aqueous solution using dried living waste sludge. The effects of operation variables, such as temperature, cell concentration and agitation speed was investigated. Sorption kinetics and parameters were conducted. The kinetic experimental data were fitted to first-order-kinetic model. It was shown that the highest dye removal capacity was found at 158 RPM. First-order-kinetic model for 158 RPM showed the best fit.*

Keyword — Biosorption, Congo red, microbial biomass.

1. Introduction

Dye is widely used in the industries like textile, paper, plastic, food, and cosmetic and it is an easily recognized pollutant. Dyes may significantly affect photosynthetic activity in aquatic life due to the presence of aromatics, metals, chlorides, and so forth, in them. Many of the dyes used in the industries are stable to light and oxidation, as well as resistant to aerobic digestion. Congo red (CR) is a benzidine-based anionic disazo dye, this dye is known to metabolize to benzidine, a known human carcinogen. In this present work, Congo Red (CR) was chosen as a model dye due to its toxicity and consequent environmental concern. Effluent containing CR is produced from textiles, printing, dyeing, paper, and plastic industries. The substance is considered as toxic. Indeed, this anionic dye can cause allergic reactions and can also be metabolized to benzidine, a known human carcinogen. Yet, the treatment of CR contaminated wastewater can be complicated due to its complex aromatic structure, which leads to a bio-physico-chemical and thermal stability of the dye, and thus to its resistance to biodegradation and to photo-degradation. The objective of this work was to investigate the potentialities of a low cost and available mixed microbial biomass waste; industrial sewage sludge for adsorptive removal of a textile dye: Congo Red. The effects of several operating parameters on the biosorption process were investigated.

2. Materials and Methods

2.1 Preparation of biosorbent

A mixed microbial culture was collected in the form of raw sludge from the effluent treatment unit of a petroleum industry situated in West Bengal, India. After primary clarification, the sludge was washed with distilled water several times. Then it was dried at oven at 45-50^{o}C, to remove the excess moisture associated with the sludge. The temperature was not increased more than 50^{o}C to avoid the chance of death of organism. The drying process was carried out till a constant weight is obtained. Then the dried biomass was used for further adsorption studies. The size distribution of dried living biomass (DLB) was not checked and no physical or chemical modification was done on to test for the adsorptive capacity of the raw DLB. Congo red is an anionic azo dye having IUPAC name as 1-napthalenesulfonic acid, 3, 3-(4, 4-biphenylene bis (azo)) bis (4-aminodisodium) salt. The dye was obtained from M/s Merck. The stock solution of Congo red was used in this study (100 mg/L) was prepared by dissolving Congo red in distilled water. Later on, solutions of dye with different desired concentrations were prepared by dilution the stock solution.

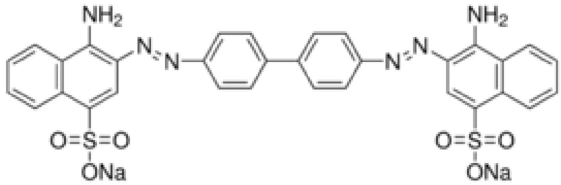


Fig1: Molecular structure of Congo red

2.2 Preparation of media

As the adsorption experiments were carried out with living biomass, therefore mineral salt (MS) media was taken for the experiment. As MS media does not contain any carbon source, therefore very less amount of dextrose (0.2 mg/L) was added with MS media in every batch of experiment, just to maintain the survival of the biomass.

2.3. Batch adsorption study

Batch experiments were performed to study the effects of important parameters such as effect of concentration of dye, amount of adsorbent (DLB), RPM and temperature. For this, 100 ml of media was taken in 250 ml of airtight volumetric flasks with a desired concentration of Congo red and weighted amount of DLB. The flasks were kept under continuous shaking for proper adsorption. At an interval of 24 hrs of contact, the samples were collected, centrifuged at 7000 rpm for 5 mins, and the optical density (OD) of supernatant was analyzed at μ_{max} 497 nm (UV-Vis Spectrophotometer, Shimadzu), for determination of concentration of residual dye. After measurement of concentration, the cell pellet and solution was reintroduced into the system. For estimation of kinetic and thermodynamic parameters of congo red adsorption, an entire set of batch experiments were performed at different adsorbent dosage (0.18 gm, 0.24 gm and 0.36 gm), rotational speed (70, 105, 158 rpm), temperature variation (25^{o}C, 30^{o}C, 37^{o}C) and dye concentration variation (25 mg/L, 50 mg/L, 75 mg/L). As the growth of biomass during the batch time was minimal, therefore it was assumed that removal of Congo red is not taking place by biodegradation or assimilation by microbial cell, but predominantly by adsorption on the cell. To calculate the dye removal, the following formula was used

$$\% \text{ removal} = \frac{Co - Ce}{Ce} \times 100 \quad \frac{mg}{g} \qquad (1)$$

With C_0 and C_e (mg/L) are, respectively, the initial dye concentration in the solution and concentration at equilibrium.

RESULT AND DISCUSSION

3.1 Influence of contact time

Contact time studies are helpful in understanding the amount of dye adsorbed at various time intervals by a fixed amount of the adsorbent (0.18 g for DLB) at various dye concentration (25 mg/L, 50 mg/L, 75 mg/L). It was observed that increase in dye concentration increased the time to reach its equilibrium value irrespective of DLB concentration (data not shown). Therefore, uniformly, 72 hrs of contact time was taken for further investigation, because maximum 72 hrs were needed to reach equilibrium when initial dye concentration was 75 mg/L.

3.2 Effect of dye concentration and DLB on removal efficiency

The batch adsorption study result indicated that 50 mg/L dye concentration showed highest percentage reduction, followed by 25 mg/L dye and 75 mg/L dye concentration respectively (Fig.2), irrespective of the DLB concentration. Therefore further experiments on influence of temperature and RPM on adsorption capacity were carried out with 50 mg/L of initial Congo red concentration. At 75mg/L of dye, the removal percentage is lesser compared to the other concentration tested. The probable reason may be that this concentration being higher, may pose inhibition to the living cell, and so they may shrink in size and the surface area becomes less. From fig. 2 it is also evident that with increase in mass of biomass adsorbent, the percentage removal increased for all concentration of dye. This may be due to an increase in number of active sites of the adsorbent material with increasing amount of the adsorbent.

3.3 Influence of shaking speed on dye removal

Speed of rotation of the dye solution with adsorbent has influence on dye removal efficiency. Rotation speed has been varied at 70 rpm, 110 rpm and 158 rpm. The result indicated that with increase in rotational speed, increase in adsorption of Congo red dye occurred which is the direct influence of increase in mass transfer (transfer of dye from the solution to the cell wall) with the increase in speed of rotation (Fig 3(a)-3(c)).

3.4 Modeling of the kinetics

To calculate the dye removal, biosorption capacity at equilibrium time (Q_e) and biosorption removal efficiency were determined respectively according to the following equations:

$$Q_e = [(C_o - C_e) * (V/M)] \text{ (mg/g)}$$

$$\textit{Sorption removal percent} = [(C_o - C_e)*100] / C_o (\%)$$

With C_o and C_e (mg/L) are, respectively, the initial dye concentration in the solution and concentration at equilibrium. V is the volume of the solution, and M is the mass of dry adsorbent used (g).

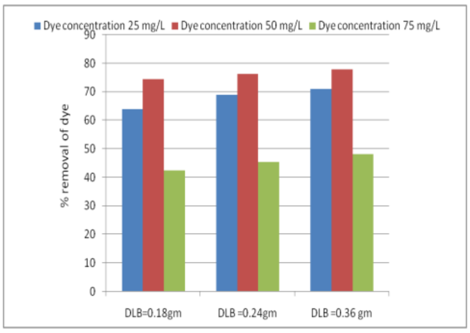
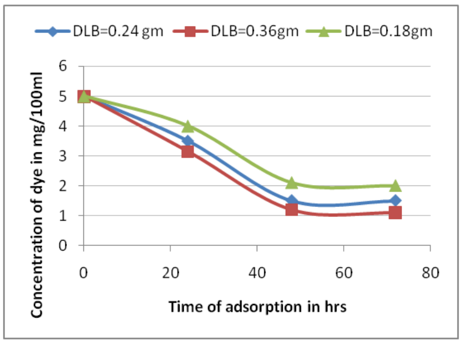
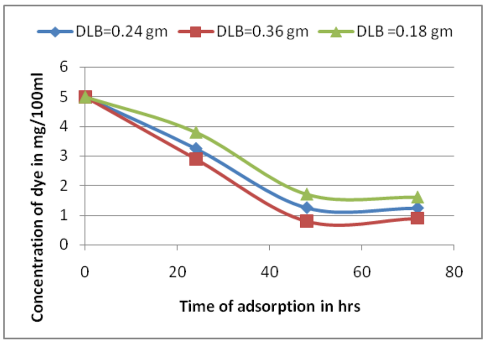


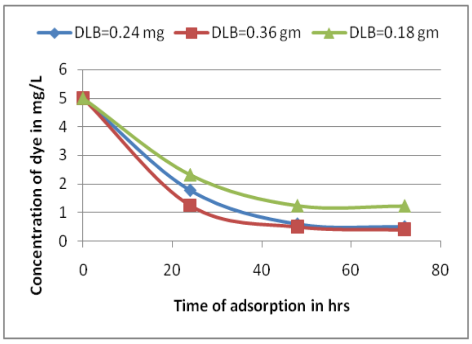
Fig.2 Effect of initial concentration dye on its removal.



3(a)



3(b)



3(c)

Fig. 3 Profile of dye removal with shaking speed of a) 70 rpm b) 110 rpm c) 158 rpm

In order to predict the mechanism involved during of the present biosorption process, two kinetic models were used to fit the experimental data, namely, first-order models. The best-fit model was selected based on both the linear regression correlation coefficient (R^2). The mathematical equations of these models are given in table below.

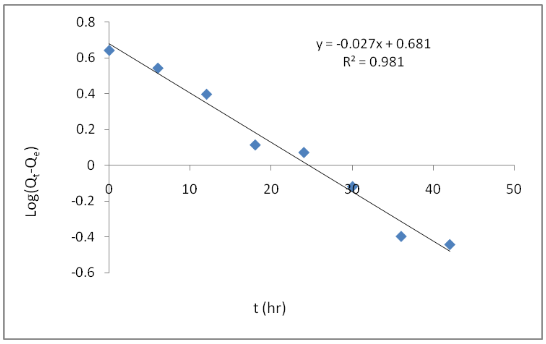


Fig. 4 first order kinetic model at 158 rpm

Table1 : Equations of the two kinetic models.

Kinetic model	Equation	Integrated form
First-order	$dq/dt= K_1(Q_e\text{-}Q)$	$\log(Q_e\text{-}Q)= \log Q_e\text{-}(K_1/2.303)t$

The parameters of both kinetic and equilibrium modelling showed that the kinetic data were accurately described by the first-order-kinetic model. Result showed a good fit with first-order-kinetic model. First-order-kinetic model for 158 RPM showed the best fit.

4. CONCLUSION

The aim of the present work was to contribute in developing an effective and inexpensive technology for removing dyes from aqueous solution by waste sludge as a biosorbent. Congo Red (CR) was chosen as a dye model. The influences of RPM, temperature, cell mass, and dye concentration on the removal of Congo red were studied. These results revealed that Congo red removal increases at increasing cell mass and comparably decreases with decrease in RPM. It was shown that the highest dye removal capacity was found at 158 RPM. The parameters of both kinetic and equilibrium modelling showed that the kinetic data were accurately described by the first-order-kinetic model. First-order-kinetic model for 158 RPM showed the best fit.

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