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Biosorption of acid violet dye from aqueous solutions using native biomass of a new isolate of *Penicillium* sp.

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ABSTRACT

Laboratory investigation of the potential use of *Penicillium* sp. as biosorbent for the removal of acid violet dye from aqueous solution was studied with respect to pH, temperature, biosorbent, initial dye concentrations. *Penicillium* sp. decolourizes acid violet (30 mg l^{-1}) within 12 h agitation of 150 rpm at pH 5.7 and temperature of 35 °C. The pellets exhibited a high dye adsorption capacity (5.88 mg g^{-1}) for acid violet dye over a pH range (4–9); the maximum adsorption was obtained at pH 5.7. The increase of temperature favored biosorption for acid violet, but the optimum temperature was 35 °C. Adsorption kinetic data were tested using pseudo-first-order, pseudo-second-order and kinetic studies showed that the biosorption process follows pseudo-first-order rate kinetics with an average rate constant of 0.312 min^{-1}. Isotherm experiments were conducted to determine the sorbent–desorption behavior of examined dye from aqueous solutions using Langmuir and Freundlich equations. Langmuir parameter indicated a maximum adsorption capacity of 4.32 mg g^{-1} for acid violet and R_L value of 0.377. Linear plot of log q_e vs log C_e shows that applicability of Freundlich adsorption isotherm model. These results suggest that this fungus can be used in biotreatment process as biosorbent for acid dyes.

1. Introduction

Control of pollution is one of the prime concerns of society today. With economic constraints on pollution control processes, affordable and effective methods have become a necessity. Untreated or partially treated wastewaters and industrial effluent discharges into natural ecosystems pose a serious problem to the ecosystem and the life forms (Bhole et al., 2004). Among the various pollutants present in industrial wastewaters, colour is considered to be a 'visible pollutant' and is most difficult to remove from wastewater (Raghuvanshi et al., 2004). Dyes vary in chemical composition, but share common features. They are highly stable to external agents such as chemical compounds and light. Dyes tinctorial value is high: less than 1 ppm of dye concentration produces obvious coloration. This makes it difficult to remove colour from the wastewater. Dyes may significantly affect photosynthetic activity in aquatic life because of reduced light penetration and may also be toxic to some aquatic life due to the presence of aromatics, metals, chlorides etc, (Daneshvar et al., 2007). About 100,000 commercial dyes are manufactured including several varieties of dyes such as acidic, basic, reactive, azo, diazo, anthraquinone based meta complex dyes. Over 10,000 dyes with an annual production of over 7×10^5 metric tons are commercially available (Daneshvar et al., 2007; Vijaykumar et al., 2007). Due to inefficiencies of the dyeing process in textile industry, 10–15% of the dyes are lost in the effluents. It is estimated that 2,80,000 tons of textile dyes are discharged in such industrial wastewater every year world wide. The majorities of these dyes are toxic, mutagenic, carcinogenic and posses a potential health hazard to all forms of life (Aksu, 2005; Xian et al., 2007). A range of conventional treatment technologies for the removal of textile dyes have been investigated extensively. The used methods are carbon adsorption, chemical precipitation, flocculation, photolysis, photodecomposition, reverse osmosis, ion pair extraction etc. Among these treatment technologies, adsorption has been shown to be the most promising option for the removal of non-biodegradable organics from aqueous effluents, activated carbon being the most common adsorbent for this process due to its effectiveness and versatility (Aksu, 2005). But activated carbon has also some disadvantages. Both chemical and thermal regeneration of used carbon is expensive, impractical on large scale and produces additional effluent and results in considerable loss of the adsorbent. These physical and chemical methods have major operational problems and have inherent drawbacks as they generate a significant amount of sludge or cause secondary pollution due to the formation of sludge or hazardous by-products (Hefang et al., 2004).

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Attempts made to search for the use of economical and efficient alternative biosorption materials such as baggage pith (Amin, 2008) and fly ash (Gupta et al., 2000) etc. have produced results with low adsorption capacity and disposal problem of large quantity of sorbents. Since 1980s, the live and dead biomass or their derivatives into adsorption studies have been successfully employed, especially for the removal of heavy metals and other pollutants from wastewater (Kiran et al., 2005; Sintuprapa et al., 2000; Yesilada et al., 2003). The term "biosorption" refers to the removal of unwanted organic and inorganic species, which include dyes, metals and odor causing substances by microbial biomass through a combination of active and passive transport mechanisms including ion-exchange and complexation (Kiran et al., 2005). Microbial cell surface carry various types of functional groups like amino, carboxylate, phosphate and hydroxyl which are responsible for the sequestration of hazardous materials from industrial effluents (Gadd and White, 1985). The fungal biomass has a positive potential for the development of cost-effective biosorbents. Fungi are easily grown and produce high yields of biomass. Furthermore, fungi are extensively used in a variety of large scale industrial fermentation processes, and waste biomass from these processes is a potential source of cheap biosorbent material (Zeroual et al., 2006). In the present investigation, the biomass of *Penicillium* sp. is used as a biosorbent and its capacity to remove acid violet dye is evaluated. Previously, different *Penicillium* species have been focused only on the removal of metal ions from wastewaters (Ming et al., 2008; Sintuprapa et al., 2000). Except very few reports, a survey of literature showed that little work has been done so far on dye removal process using *Penicillium* sp. as biosorbent.

In this study, the *Penicillium* sp. was used for the biosorption of acid violet dye in batch system. The biosorption kinetics is studied to explore the effect of initial dye concentration, temperature, pH and biosorbent concentration on the dye removal. The biosorption phenomena have been shown by the Freundlich and Langmuir adsorption models. The experimental data were also analyzed for first and second order kinetic models.

2. Materials and methods

2.1. Chemicals and dye solution preparation

The acid violet was provided by M/s J. C. Enterprises, Thane (Maharastra), India and all other chemicals were procured from S.D Fine Chemicals Mumbai, India. The synthetic dye solution was prepared by dissolving weighed amount of acid violet in 1 L of deionise water and filtered for sterilization. The stock acid violet solution was stored in the dark. The dye was added with the concentration of 0.03 g l^{-1}. All other chemicals used were of analytical grade and highest purity.

2.2. Microorganism and culture condition

Penicillium sp. was isolated from coal samples collected in and around the thermal power station, Raichur, Karnataka, India and it is identified in Agharkar Research Institute, Pune, India (Ref N0.3/426/2007/8580). The coal sample was suspended in saline and kept on shaker for about 30 min. This suspension was spread on mineral salt medium agar plates containing acid violet (30 mg l^{-1}) and incubated at 37 °C for 1 week. The fungus was selected based on its ability to form a clear halo on agar plate containing acid violet. Among the seven isolated fungal strain, one fungal strain was selected on its high dye decolourization zone on agar plate. The selected strain was identified as *Penicillium* sp. based on various cultural characteristics, morphology of fungus and conidiophores. The fungus is deposited in National Collection of Industrial Microorganisms (NCIM), Pune, India with accession number NCIM 1339.

The fungal mycelium was inoculated in to 500 ml Erlenmeyer flask containing 100 ml of mineral salt medium with 1 g of glucose and cultivated at 37 °C under static condition. The composition of culture medium was (g l^{-1}): K_2HPO_4 6.3; KH_2PO_4 1.8; NH_4NO_3 1; $MgSO_4 \cdot 7H_2O$ 0.1; $MnSO_4$ 0.1; $CaCl_2 \cdot 2H_2O$ 0.1; $FeSO_4 \cdot 7H_2O$ 0.1; $Na_2MoO_4 \cdot 2H_2O$ 0.006; pH 5.7 ± 0.1. Mycelium pellets cultured for 72 h were filtered with nylon cloth and then washed with deionized water for several times. The biomass was applied as dye adsorbent. The fungus was maintained on PDA medium slant.

2.3. Batch biosorption experiments

Batch biosorption experiments were conducted in 100 ml conical flask on a magnetic stirrer at 150 rpm running at different time intervals. All the experiments were carried out at 35 °C temperature. The concentration of dye before and after sorption was determined spectrophotometrically by monitoring the changes in absorbance at λ_{max} (630 nm) of acid violet dye. All the batch biosorption experiments were carried out in triplicate at optimum pH of 5.7.

The influence of pH was determined by agitating 0.5 g of fungal mycelium with 50 ml of dye solution (acid violet with initial concentration 30 mg l^{-1}) at different pH ranging from 3 to 9 using magnetic stirrer. Agitation was provided for 12 h which is enough time to reach equilibrium with a constant agitation speed of 150 rpm.

The effect of temperature was studied at different temperatures (15, 20, 25, 30, 35, 40 and 45 °C). In a typical biosorption experiment, fungal biomass (0.5 g wet weight) in 50 ml of the dye solution (30 mg l^{-1}) was agitated magnetically at 150 rpm for 12 h.

The effect of biomass concentration on the amount of dye adsorbed was predicted by agitating with different fungal biomass with 50 ml of acid violet solution of initial dye concentration 30 mg l^{-1} for 12 h of contact time at an optimum pH 5.7.

Biosorption equilibrium studies were carried out by agitating 0.5 g of mycelium pellet in a series of conical flasks containing each of 50 ml of acid violet solution of different dye concentration (30, 60, 90 mg l^{-1}) at predetermined temperature of 35 °C. Agitation was provided for 12 h which is sufficient to reach equilibrium. After equilibrium the residual concentrations of dye in each sample were analyzed as before.

Kinetic experiments were carried out by agitating 0.5 g of mycelium pellet in a series of conical flasks each containing 50 ml acid violet solution of known concentration using magnetic stirrer running at different contact time intervals at temperature 35 °C. All the kinetic experiments were carried out in triplicate at optimum pH of 5.7.

2.4. Dye uptake

The amount of dye adsorbed onto unit weight of adsorbent, q_e (mg g^{-1}) was calculated using the mass balance equation as follows:

$$q_e = \frac{(C_0 - C_e)V}{M} \quad (1)$$

Where C_0 and C_e represent the concentration of acid violet (mg l^{-1}) in the solution at time, $t = 0$ and at any time t (h). V is the volume of solution and M is the amount of biosorbent used (g).

2.5. Decolourization assay

Decolourizing activity expressed in terms of percent decolourization. The decrease in absorbance was monitored at λ_{max} of acid