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Bio sorption of acidic dye from an aqueous solution by a marine bacterium, *Planococcus*sp. VITP21

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Abstract: The marine bacterium, *Planococcus*sp.VITP21 from Kumta costal region of Karnataka, India was investigated for the sorption of acidic Brill Blue dye. The effect of different parameters such as pH, initial dye concentration, initial salt (NaCl) concentration and initial Cr (III) concentration on bio sorption were investigated. The parameters were analysed using Langmuir, Freundlich and Temkin adsorption isotherms. On comparison, Freundlich was found best fitted with regression coefficient and biosorption capacity of .99 and 8.9mg/gm respectively. The FT-IR analysis confirmed the interaction of biosorbent with the dye. The results indicated that marine biosorbent, *Planococcus* sp. VITP21 has a very good potential for removing acidic dye from aqueous solution under different operating conditions.

Keywords: *Planococcus*sp., marine bacteria, anionic dye, adsorption isotherms, FT-IR and biosorbent.

Introduction

The dyes have wider application in industries like textile, paper, cosmetic, pharmaceutical or leather. The coloured effluent from these industries released into the environment, increase the chemical and biological oxygen demand of the water and also leads to increase in toxicity and decrease in light penetration that affects the aquatic life. Dyes used in the industries can be classified as anionic, cationic, reactive and direct dyes. Anionic dyes are water soluble and stable, and cannot be treated by conventional treatment methods[1]. As an alternative, adsorption and bio sorption treatment has proved to be effective method with high adsorption capacity[2]. Though adsorption by activated carbon is the promising method, it is not cost effective[3]. Bio sorption differs from adsorption in the way that the adsorbent material being used is living or dead microorganism or its derivatives[4,5,6,7].In the present study, an investigation was performed by using marine bacteria, *Planococcus* sp.VITP21 as biosorbentfor the removal of anionic industrial dyeBrill Blue(BB) from aqueous solution.

Experimental

Biosorbent and dye solution preparation

The biosorbent used in the present study was a marinebacterium,*Planococcus*sp. VITP21[8],an isolate from Kumta coast of Karnataka, India. Bacteria was grown for 24 hours in Luria Bertani media under optimal condition (35ºC,7 pH, 120 rpm and 4 % w/v NaCl),centrifuged at 10000 rpm for 15 minute and biomass (pellet) was used as biosorbent material. 0.5 gm (wet weight) of biosorbent was used in all the studies for bio sorption of dye. Thesynthetic industrial dye (biosorbate), BrillBlue (Asiatic ColorChem., Ahmadabad) was purchased from local shop and used for the present investigation.The dye was acidic and used as such without any pre-treatment. The aqueous dye solution was prepared by dissolving 1000mg of appropriate dye in 1 litre of distilled water and used as stock solution for all the experiments.

Bio sorption experiment

The batch bio sorption studies were carried out by treating 50ml of dye solution, Brill Blue with 500mg (wet weight) of biomass in Erlenmeyer flask for 22 hours at 120 rpm and 298 K in an orbital shaker for all the experiments (Initial dye concentration = 50 mg/l and pH 5).The parameters such as initial pH (3, 5, 7 and9), initial dye concentration (10 to 40mg/l), initial salt concentration (2, 4, 6 and 8 %(w/v) NaCl) and initialCr (III) concentration(50,100,150 and 200 mg/l) varied accordingly for different experiments. pH of dye solution was adjusted using 0.1 N HCl and NaOH solutions, prior to addition of bio sorbent.Dye adsorption was read at 544 nm forBrill Blue using UV –Vis spectrophotometer. Theinitial and final absorbance was estimated after samples were centrifuged at 10000 rpm for 15minutes. The percentageremoval of dye and amount of dye adsorbed (mg/g)were calculated using the following equations :

$$\text{Percent Removal} = \frac{\text{Initial absorbance} - \text{final absorbance}}{\text{initial absorbance}} \times 100$$

$$\text{Amount adsorbed } (q_e) = \frac{C_o - C_e}{m}$$

Where C_o and C_e are the initial and the final dye concentration in (mg/l) respectively, m is the mass of biosorbent in (mg/l).

Analytical methods

FT-IR analysis was done in a range of 500-4000cm^{-1} to identify the active sites present on the surface of the bio sorbent and to investigate the bio sorption pattern[11]. The pure biosorbent and biosorbentloaded withdye were dried at 50ºC for a time period of 24 h and mixed with KBrand spectrum was recorded[12].U-2800 Spectrophotometer was used to determine the maximum wavelength for the dye, Brill Blue and the maximum wavelength was at 544nm.

Results and Discussion

Effect initialpH and dye concentration

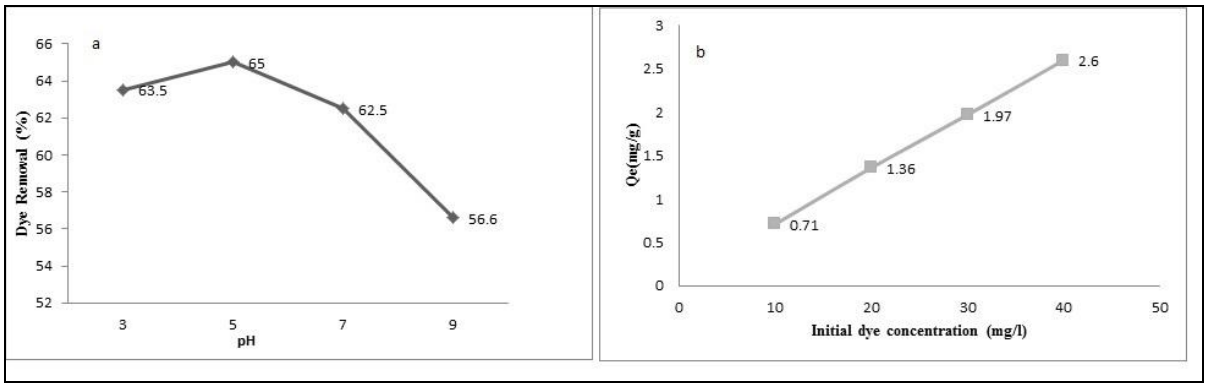

Figure 1.Effect of (a) initial pH and (b) initial dye concentration on dye removal by biosorbent, *Planococcus* sp. VIT P21

The effect of different initial pH (3, 5, 7 and 9)and dye concentration (10 to 40mg/l) was studied to investigate the bio sorption of Brill blue dye from aqueous solution by the marine bacteria, *Planococcus* sp.VITP21 (Figure 1a). The experiments were performed at 120 rpm and 298 K with the initial dye concentration of 40 mg/l.Bio sorption of dye at different pH showed increase in dye removal from 63.5% (pH 3) to 65% (pH 5), followed by a decrease from 62.5% (pH 7) to 56.6% (pH 9). Thus, optimum pHwas observed at lower pH 5 aselectrostatic interaction between the positively charged bio sorbent and the negatively charged anionic dye was enhanced and hence the removal of dye also increased[13]. Figure 1b shows the effect of initial dye concentration (10mg/l to 40 mg/l) onbio sorption of dye and it revealed that the amount of dye adsorbed per gram of bio sorbent (q_e) increased with increase in dye concentration (.71, 1.36, 1.96 and 2.6mg/g for 10, 20, 30, and 40mg/l respectively).As the dye concentration increased, $q_e$also increased whichindicates the development of concentration gradient that actsas drivingforce[14].

Effect of different NaCl andCr (III) concentration

The effect of different initial NaCl(2, 4, 6 and 8 % (w/v) NaCl) and Cr (III) (50, 100, 150 and 200 mg/l) concentration on bio sorption of Brill blue dye was carried out with 40 mg/l of initial dye concentrationat pH 5 (Figure 2a). The results revealed that the dye removal increased (69% to 79%) with increase in NaClconcentration (2% to 8%).The increase in bio sorption with increasing ionic strength was due to increase in the electrostatic interaction between the dye ions and the adsorbent surface[11].Thus the study reveals that the biosorbent is efficient in removing synthetic dyes from industrial waste water containing NaCl. Figure 2b shows the effect of initial Cr (III) concentration on dye removal and it did not affect bio sorption of dye, whereas it slightly increased the removal rate from 64 to 71 % for 50 to 200 mg/l ofCr (III) concentration[11].

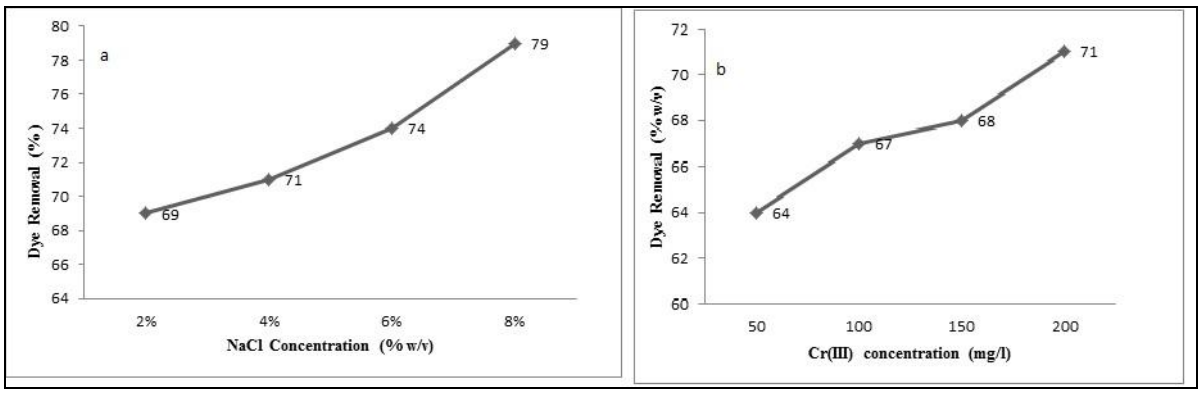

Figure 2: **Effect of (a) initial salt concentration and (b) Initial Cr (III) concentration on dye removal by biosorbent,*Planococcus* sp. VITP21**

Adsorption isotherm models

The interactive behaviour between the solute and the adsorbent can be described by the equilibrium adsorption isotherms, Langmuir, Freundlich and Temkinisotherm and they arealso used to design adsorption system.The expression for the linear form of Langmuir adsorption isotherm is:

$$\frac{C_e}{q_e} = \frac{1}{bQ_m} + \left(\frac{1}{Q_m}\right)C_e$$

Where C_e is the solute concentration (mg/l) at equilibrium, q_e is the amount of adsorbate adsorbed at equilibrium (mg/g), b is the Langmuir constant related to the biosorption energy (L/mg), Q_m is the maximum sorption capacity relating to complete monolayer coverage (mg/g).Figure 3a depictsthe experimental results fitted by Langmuir model.The analysis of the Langmuir equation is done by estimating a dimensionless equilibrium parameter R_L which is given by the expression [15], $R_L = \frac{1}{1 + bC_e}$, WhenR_L is greater than zero and less than one, the adsorption is favourable, $R_L$is equal to1, linear adsorption takes place, $R_L$is equal to 0 leads to irreversible adsorption whereas when R_L is greater than1 unfavourable adsorption takes place.The R_L value for the dye, Brill blue is 0.471 is between 0 and 1 that means the process is favourable[16].The maximum monolayer coverage of dye was found to be 8.9mg/g with R^2 value of 0.88.

The linearized form of the Freundlich equation is:

$$\log q_e = \log K_f + \frac{1}{n}\log C_e$$

Where, K_f (l/mg) is the Freundlich constant and nthe Freundlich exponent.K_f and n can be determined from the linear plot of log q_e versus log C_e (Figure 3b). K_F is related to the adsorption capacity of the adsorbent [1].1/n is the measure of adsorption intensity or surface heterogeneity with the value ranging between 0 and 1is said to be favourable [3]. In the present study, the value of K_F for Brill blue is 0.297 l/mg and the value of 1/n is between 0 and 1 (0.818) which indicates adsorption is favourable. The R^2 value Brill blue is 0.999 shows that experimental result fit well in the Freundlich adsorption isotherm [18].

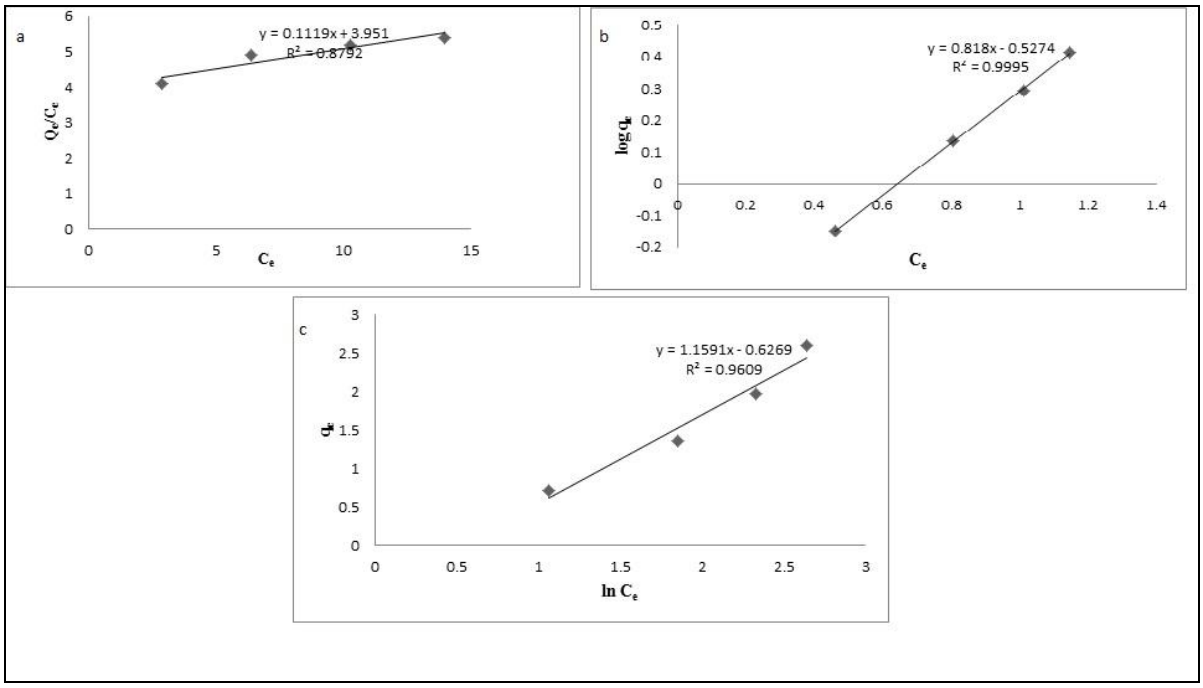

Figure 3 (a) Langmuir isotherm (b)Freundlich isotherm (c) Temkin isotherm of Brill blue dye adsorption onto biosorbent, *Planococcus* VITP21

The Temkin adsorption isotherm assumes that the heat of adsorption increases linearly on a surface[17] andis assumed to be characterized by uniformly distributed binding energies, up to some binding energy which is maximum[19].The q_e v/s lnC_e.was presented in the figure 3c.

$$q_e = BlnA_t + BlnC_e \quad , \qquad B = R.T/b_t$$

Where A_t is the Temkin isotherm equilibrium binding constant (L/g), $b_t$is the Temkin isotherm constant, R is universal gas constant (8.314J/mol/K), T denotes Temperature at 298K, and B represents constant related to heat of sorption (J/mol**).**In the present study for the Brill blue dye, B and A_t are 1.1591 J/mol and 0.5822 l/gm respectively and the values are in accordance with the literature[19,20]and the R^2 value is 0.96.A positive value of b_t(2137.496J/mol) indicates exothermic process[21].

Isotherm	**Parameters**	**Values**
Langmuir	Q_m (mg/gm)	8.936
	K_L (l/mg)	0.028
	R_L	0.471
	R^2	0.8792
Freudlich	K_F (l/mg)	0.2969
	1/n	0.818
	R^2	0.9995
Temkin	B (J/mol)	1.159
	b (J/mol)	2137.496
	A_t (l/gm)	0.58
	R^2	0.96

FT-IR Analysis

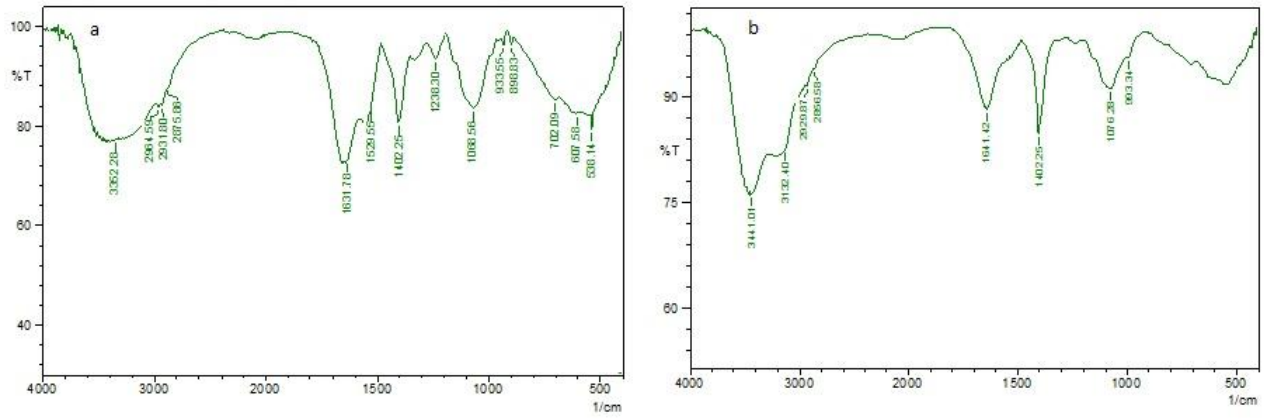

Figure 4: FT-IR spectra of (a) Biosorbent, *Planococcus*VITP21 (b) Biosorbent, *Planococcus* VITP21 after interaction with brill blue dye

The FTIR analysis of marine bacteria, *Planococcus*sp.VITP21 revealed about the different functional groups of biosorbent that are available for interaction with dye.The spectrum of bio sorbent before (control) and after sorption are shown in the figure 4.The peak in the region of 3352.28/cm (OH and/or NH group) and 2964.59/cm (C-H stretching of aliphatic group) was shifted to 3132.40/cm and 2929.87/cm respectively [12]. 2875.86/cmpeak (C-CH_3 group) in control was observed to change to 2856.58/cm [23]. The change in the peaks at 1631.78/cm (COOH) to1641.42/cm, 1068.56/cm (C-O) to 1076/cmand 933.55/cm(P=O, P-O-C, P-OH stretching)to 993.34/cm were also observed [22]. Thus variation in the peak confirms the interaction of brill blue dye with the bio sorbent.

Conclusion

The study investigated the biosorption potential of marine bacteria, *Planococcus*sp. VITP21 to remove Brill blue dye from the aqueous solution. The effect of different parameters such as pH, initial dye concentration, initial salt (NaCl) concentration and initial Cr (III) concentration on bio sorption were investigated. The experimental results were analysed using Langmuir, Freundlich and Temkin adsorption isotherms. On comparison, Freundlich was found best fitted with regression coefficient and biosrption capacity of .99 and 8.9 mg/gm respectively. The FT-IR analysis confirmed the interaction of biosorbent with the dye. The results indicates that marine biosorbent, *Planococcus* sp. VITP21 has a very good potential for removing acidic dye from aqueous solution under different operating conditions.

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