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Research Article

Sugarcane Bagasse - A Potential Low Cost Bioadsorbent for the Removal of Reactive Blue Dye

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Abstract

The aim of the present study is to adsorb reactive blue from aqueous solution onto sugarcane bagasse. The physicochemical parameters such as initial dye concentration (10-50 mg/l), adsorbent dose (0.1- 0.5 g), contact time (24-240 hrs), pH (2-12) and temperature (20-60^{0}C) were employed to assess the percentage decolourisation of reactive blue dye. The phytotoxicity and cytotoxicity studies of untreated and treated reactive blue on *Vigna radiata* and *Aillum cepa* were assessed. The results indicated that the optimum conditions for the maximum removal of reactive blue occurred at pH 2 with 100mg/L of dye at room temperature (30^{0}C) within 120 hrs of incubation using 0.4g adsorbent. Scanning of the absorbance between 200 and 800 nm showed that three peaks disappeared in the treated dye solution (585, 447 and 394nm) and the new peaks were formed at 315 and 259nm which confirms the decolourisation of reactive blue. In phytotoxicity study, the germination percentage, root and shoot lengths of *Vigna radiata* were high in control and treated dye solution when compared with untreated dye solution. In cytotoxicity study, the untreated dye solution induced chromosomal aberrations in root tip cells of *Allium cepa* such as disturbed anaphase, abnormal metaphase, disturbed telophase, bridge at telophase, whereas in control and treated onion bulbs they show normal divisions. Hence, phytotoxicity and cytotoxicity studies prove that the treated dye solution was nontoxic.

Keywords: Adsorption, sugarcane bagasse, reactive blue, decolourisation, cytotoxicity, phytotoxicity.

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Introduction

Environmental pollution has recently become a serious problem worldwide [1]. Colour is one of the primary contaminants in wastewater and has to be removed from wastewater before discharging into water bodies [2]. Synthetic dyes are extensively used in various industries such as textile, leather tanning, paper and pulp production, food products. [3]. Discharge of huge amount of dyes into aquatic water bodies, accompanied by organics, bleaches and salts, can change the physical and chemical properties of fresh water. In addition to their unwanted colours, some dyes may degrade to produce carcinogens and toxic products [4]. Industries utilize several different methods to treat wastewater such as, flocculation and coagulation [5], ozonation and oxidation [6], membrane separation [7] and sorption by activated carbon [8].

Currently, different physical and chemical treatments are used to treat dye wastewater. These processes are not economical and cannot be successively used to treat wide range of dye wastewater. Conversely, adsorption proves to be a novel and cost-effective approach for the wastewater treatment [9, 10]. Adsorption has attracted increasing interest owing to its lower cost, effectiveness in producing less sludge and environmental friendliness [11, 12]. Over the last few decades, there has been an increase in the use of plant waste products for dye removal by adsorption from wastewater because of their natural availability and high degree of removal capacity under laboratory conditions [13, 14, 15].

Sugarcane bagasse is one of the primary argicultural wastes which mainly consists of cellulose (45%), hemicelluloses (28%) and lignin (18%) [16]. It contains carboxylic and hydroxyl groups, which show the capacity to adsorb the dye molecules by the ion exchange phenomena or by complexation [17]. Hence it can be used as a cheap, attractive and effective adsorbent for the removal of dyes from wastewater [18]. Keeping in view the significance of

dyes and their environmental problems, the present study is designed to explore the biosorption potential of sugarcane bagasse for the removal of reactive blue dye from aqueous solution.

Experimental

Collection of adsorbent and adsorbate

Sugarcane bagasse (SCB) was collected from local juice marker, Coimbatore, Tamilnadu. It was washed thoroughly with water to remove the colour and dried in sunlight for a week. The dried bagasse was powered and sieved to obtain uniform particle size (0.25mm) and stored for adsorption studies.

Reactive blue (C. I no: 61211, CAS Number 12236-82-7, EC Number 249-524-3, Molecular formula: $C_{29}H_{17}ClN_7Na_3O_{11}S_3$, Molecular weight: 840.10, absorption 595nm) dye used in this study was purchased from local dye market Coimbatore, Tamilnadu. The molecular structure was shown in **Figure 1**.

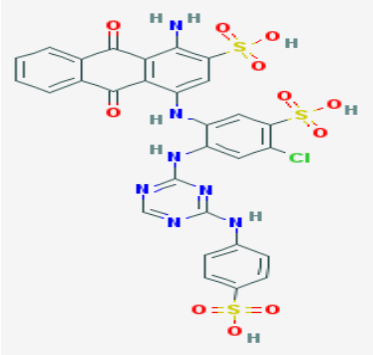


Figure 1 Molecular structure of Reactive blue (RB).

Adsorption studies

The adsorption studies were carried out for the efficiency of SCB in the removal of RB. The experiments were conducted in 100ml Erlenmeyer flasks containing different dye concentration (10-50mg/100ml), adsorbent dose (0.1-0.5g), pH (2-12), temperature (20-60^{0}C) and contact time (24-240 hrs). The pH of the solution was adjusted with 0.1N sodium hydroxide and 0.1N hydrochloric acid. Under optimised conditions, the untreated and treated solutions were filtered and centrifuged at 5000 rpm for 10mins. The clear supernatants were used for determining the decolourisation percentage

$$\text{Percentage decolourisation} = C_o - C_t / C_o \, X100$$

Where, C_o is the initial concentration of the dye solution, C_t is the final concentration of the dye solution.

UV- visible spectral analysis

Decolourisation was monitored by UV-vis spectrophotometer (Shimaduz model UV mini 1240). The colour intensity was measured between 200 to 800nm absorbance. The initial and final absorbance values of untreated and treated peaks of RB were used to determine the dye decolourisation.

Phytotoxicity study

The phytotoxicity study of RB dye was performed to assess the toxicity of dye before and after dye degradation. The studies were carried out using *Vigna radiata* (green gram) seeds. Ten seeds were grown in each treatment by watering with untreated and treated solution separately. Control seeds were grown in tap water. After 7 days, germination percentage, root length and shoot length was recorded.

Cytotoxicity study

The bulbs presoaked in distilled water were germinated in sand trays and grown in untreated and treated RB solution. The bulbs grown in tap water served as control. When the root growth reached the length of 1 to 2 cm the tips were cut, fixed and preserved. The cut root tips were fixed in 1:3 aceto-alcohols for 24 h and then stored in 70% alcohol for future use. Staining was done in 2% aceto-carmine in 45% glacial acetic acid (v/v) followed by rubbing in rust free iron needle to visualize the scorable stages under microscope [34-38].

Results and Discussion

Effect of dye concentration

The dye removal from aqueous solution provides an important driving force to overcome the mass transfer resistance between solid and aqueous phase and equilibrium is established when the energetic balance between dye concentration and adsorbent surface takes place [19]. **Figure 2** depicts that the RB dye uptake was decreased with increase in initial dye concentration from 10 to 50mg/100ml. The maximum colour removal was observed in 10mg dye concentration (74%). The uptake of dye was decreased with an increase in dye concentration, which may be due to the saturation of adsorption sites on the sorbent surface [20]. SCB removed erythromycin B and methylene blue dye (100%) in the medium amended with 100mg dye [21]. Similar results were also found by [22] who reported that 17.28 mg/g of direct violet 51dye (10mg dye concentration) was decolourised by SCB.

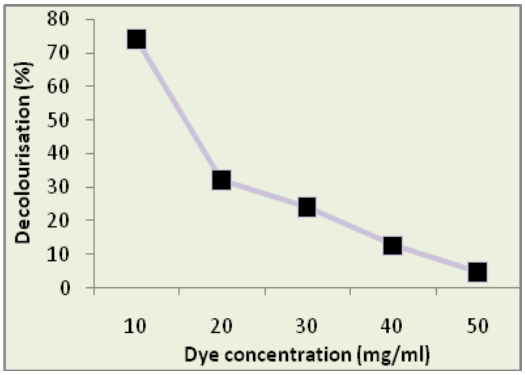


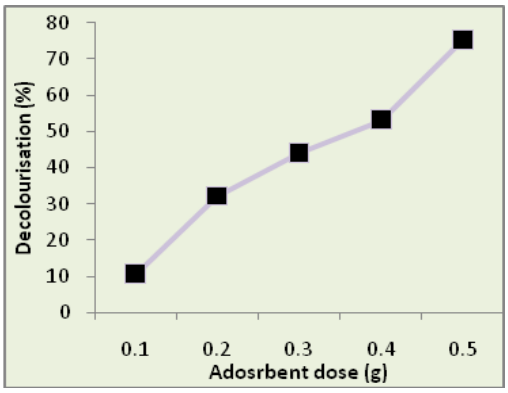
Figure 2 Effect of dye concentration

Effect of adsorbent dose

Adsorbent dose illustrates the potential of the adsorbent for the removal of a particular dye concentration. The effect of adsorbent dose (0.1 – 0.5g) on the adsorption of RB by SCB was represented in **Figure 3**. About 75% dye removal was observed at 0.4g adsorbent dose. When the adsorbent dose was further increased (0.5g) there was a decrease in the dye uptake (43%) and the dye removal was decreased at higher adsorbent doses due to the violent behaviour of the adsorbent which results decreases the surface activity of the adsorbent [23]. At high adsorbent dose, the available dye molecules are not enough to completely cover the existing binding sites on the adsorbent, which results in low solution uptake [24]. Methyl red dye was removed by SCB (76%) from aqueous solution with 0.5g adsorbent dose which supports the present study [25].

Effect of pH

The pH is one of the important parameter for dye removal from wastewater and aqueous solutions [26]. The pH of the solution might change the surface charge of the adsorbent as well as affects the degree of ionization of different pollutants [27-29]. The effect of pH on adsorption of RB on SCB was studied at various pH from (2-12). The acidic nature of the solution favours the adsorption capacity of RB by SCB. **Figure 4** indicates that the maximum (72%) dye removal was found at acidic pH (2). Further increase in the solution pH decreases the dye removal efficiency.



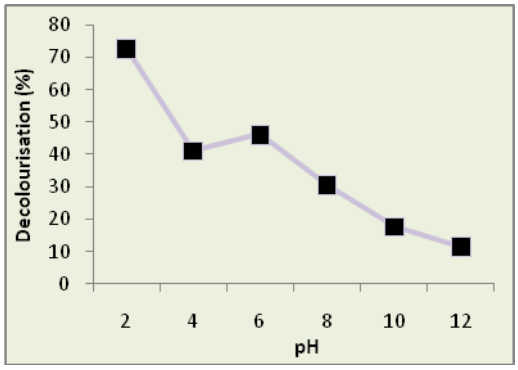


Figure 3 Effect of adsorbent dose. **Figure 4** Effect of pH.

The higher uptake of dye found at acidic condition might be due to the presence of electrostatic attraction between the positively charged active sites of the sorbent and the negatively charged adsorbate [30]. As the pH increases (above 2), a negatively charged surface sites on the adsorbent did not favour the adsorption of positively charged adsobate due to electrostatic repletion which resulted in decreased dye removal [31]. The alkaline pH does not support the adsorption of RB because of the presence of excess OH^- ions in the solution. Similar findings were reported by [31] who stated that the 90% of methylene blue dye uptake was found at acidic pH(2) using SCB.

Effect of temperature

Temperature shows significant effect on the adsorption process. The effect of temperature on RB adsorption was studied at five different temperatures 20^0, 30^0, 40^0, 50^0 and 60^0C. In **Figure 5**, the percentage of RB removal by bagasse at 30^0C was plotted. Further increase in temperature results in the reduction of decolourisation activity of SCB. The dye uptake was decreased at higher temperature which may be due to the weakening of adsorptive forces responsible for the adsorption of dye molecules on the surface of the adsorbent and also the deactivation of the surface active sites which leads to the decrease adsorption at higher temperature [10]. The rice husk removed 19.92 mg/g and 25.69 mg/g of everdirect orange – 3GC and direct blue - 67dye at 30^0C temperature [12] which coincides with the present study.

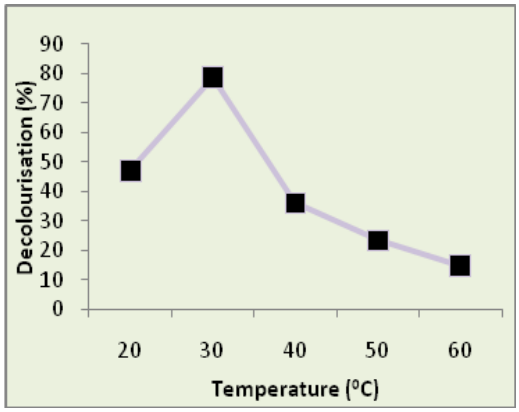


Figure 5 Effect of temperature

Effect of contact time

The contact time between the adsorbent and the adsorbate is necessary for wastewater treatment by adsorption [31]. The effect of contact time for the adsorption of RB was studied for 24-240 hrs and the results were showed in **Figure 6**. The removal of RB by SCB was maximum (77%) in 120 hr of contact time. Further increase in the contact time did not increase the dye removal because equilibrium was attained. SCB removed 87% of methylene blue dye within 150mins of contact time with SCB [32].

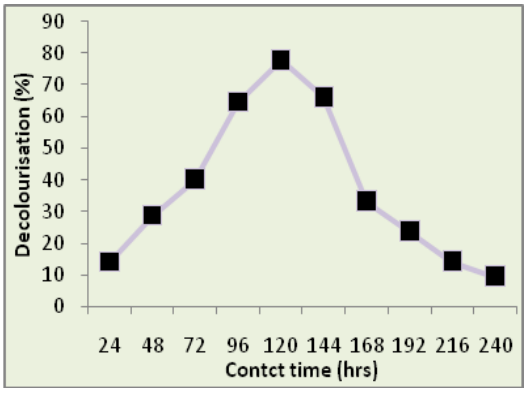


Figure 6 Effect of contact time

Optimizing conditions for Reactive blue adsorption

Based on the results of batch experiments, the optimum conditions for the maximum Reacive blue dye removal (75%) was found to be at 10mg dye concentration with 0.4 g adsorbent dose at pH 2 at 30^0C with 120hrs of incubation (**Figure 7**).

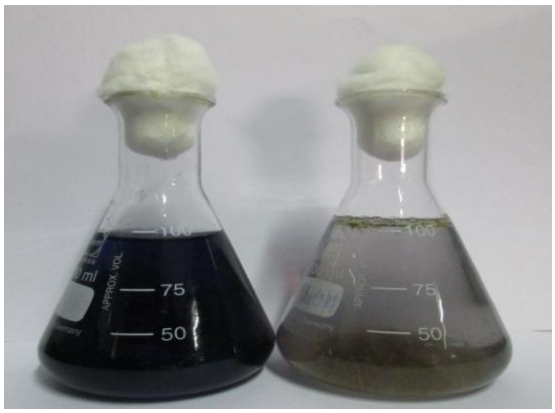


Figure 7 Optimised condition

UV- visible spectral analysis

UV–vis spectroscopic analysis was carried out to confirm the decolourization of RB dye. The spectrum of control dye and decolourised sample were recorded at 200 to 800nm wavelength. **Figure 8** denotes the adsorption spectra of RB before and after treatment in visible range. Peaks present in control dye at 585, 477 and 394nm were reduced completely and disappeared in treated dye solution. The decolourised sample showed the new peaks at 315 and 259nm which indicates that the decolourisation is due to dye degradation. The UV spectra of untreated alizarin violet N shows the initial peak at 500nm whereas in treated dye solution there is a disappearance of stated peak which responsible for the decolourisation of alizarin violet N [33].

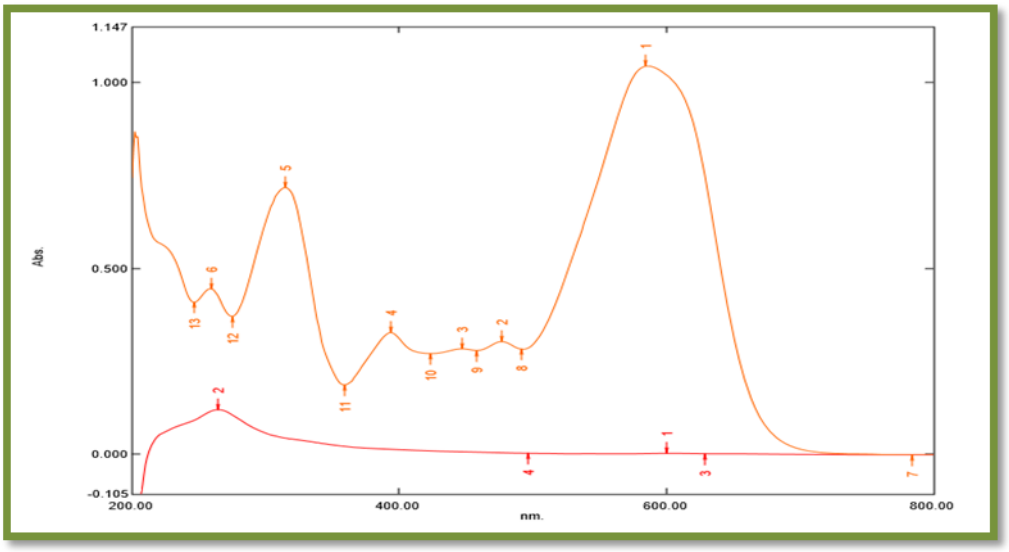


Figure 8 UV- vis spectrum of RB (before and after decolourisation with SCB).

Phytotoxicity study

The untreated and treated dye solution has a direct impact on soil fertility which was confirmed by phytotoxicity studies. The toxicity of RB dye before and after degradation was studied using *Vigna radiata* seeds. The results were depicted in **Table 1**. The study showed good germination percentage as well as root length and shoot length. Seed germination was completely inhibited in T_3 which indicates that the toxic nature of RB whereas in T_2 the seeds were grown well which shows the non-toxic nature of the treated dye solution.

Table 1 Phytotoxicity study on treated and untreated RB

Treatments	Germination Percentage	Shoot length (cm)	Root Length (cm)
T_1	100	22.03	7.76
T_2	92	19.54	5.49
T_3	0	0	0
SED	-	1.951	0.818
CD (5%)	-	1.284	0.734

T_1 (water). T_2 (treated RB), T_3 (untreated RB)

Cytotoxicity study

The common types of cytotoxic effects observed in this experiment were chromosomal bridge in anaphase and abnormal uncoiling of chromosomes during anaphase and metaphase. In some metaphases, chromosomes were arranged diagonally. In anaphases, chromosomal bridge and orientation problem in pole were observed. Table-2 describes the effect of RB on mitotic indices (the number of dividing cells with M.I. for each treatment). Number of bulbs applied for each treatment ranges from 4-10. A total of 541 to 1400 cells were scored in 4-10 slides per treatment. Maximum number of cells scored is 1400 in control. **Table**

Table 2 Effect of RB on Mitotic index in onion root tip cells

Treatments	T_3	T_2	T^1
	Untreated	Treated	Control
Duration	48h	48h	48h
No. of bulbs	10	6	4

No. of cells scored	541	986	1400
No. of dividing cells	26	114	146
Mitotic indices	2.78	2.8	4.01

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