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Removal of Colour from Crystal Violet Dye using Low Cost Adsorbents

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Abstract: Adsorption has been an effective separation process for non-biodegradable pollutants. Study of recovery of dyes reveals adsorption as an efficacious process. Many textile industries use commercial activated carbon for the treatment of dye waste. The current research is focused on the need for alternate commercial activated carbon with a cost effective, potential adsorbent. The major limitations in using commercial activated carbon in large scale are its regeneration and high cost of operation. Many researchers have studied the feasibility of using low cost adsorbents derived from natural materials, industrial waste materials, agricultural products and biosorbents as precursors. Numerous works have been reported on these adsorbents being used in the removal of heavy metals and dyes. In this paper the natural adsorbent *Rutaceae vila* carbon (RAC) and Vilvam Carbon (VC) in different dosage form was used for removal of colour from waste effluent of textile industry. These materials also evaluated for the removal of colour at different pH and time. The materials are capable of removing colour from waste water, their colour removal capacity for RAC is 97% and VC is 93 % respectively at optimal pH and temperature conditions. The experimental adsorption data fitted with Langmuir and Freundlich adsorption isotherms. The experimental result shows that the materials have good potential to remove colour from effluent when it's compared with commercial activated carbon (CAC) and it has good potential as an alternate low cost adsorbent.
Keywords: adsorbent, adsorbate, activated carbon, dye, decolourisation.

Introduction

Among the different organic pollutants of aquatic ecosystems, dyes are the large and important group of chemicals present in industrial waste [1]. Waste water from textile mill contains dyes in dissolved and suspended form and posses a serious health problem because it has a high concentration of both colour and organic matter [2-7]. It has been reported that the decolourisation of dyes is an important aspect of wastewater treatment before discharge. The colour removal was extensively studied with physiochemical methods such as coagulation, ultra filtration, electrochemical adsorption and photo oxidation. Among these methods, the adsorption process ,offers a great potential for treating effluents containing undesirable compounds and renders them safe and reusable [8-13].

The major advantage of adsorption process for water pollution control are low investment in terms of cost, simple design, easy & inexpensive operation and absence of toxic harmful substances. Activated carbon happens to be the most frequently used conventional adsorbent because of its high surface area [14-20]. But it is expensive and at the same time the high cost of regeneration and losses during regeneration made carbon black less attractive. Therefore research is on to look for economic, abundant and eco-friendly adsorbent [21-26]. A number of non-conventional low cost adsorbent used for dye removal, include fruit waste of *Prosopisn juliflora*, wood, waste orange peel, banana pith, maze cobs, barley husk, bagasse pith etc. Utilisation of agricultural waste as low cost adsorbent has great significance in India where more than 200 million tons of agricultural residues are generated annually [27-30].

The present study is to explore the feasibility of *Rutaceae vila* Fruit Shell carbon (RVC), Vilvam Fruit Shell Carbon (VC) as a low cost natural adsorbent with respect to various parameters such as colour adsorbent capacity of material with initial concentration at different doses, time, and optimum pH. The adsorption isotherm are plotted to study the removal capacity of material. The study shows that the material has good potential for the removal of colour from textile effluent.

Materials and Methods

The adsorbents used in the present investigations were commercial activated carbon (CAC), *Rutaceae vila* Fruit Shell carbon (RVC), Vilvam Fruit Shell Carbon (VC).

The material commercial activated carbon(LR) was supplied by S.D.fine chem.,Ltd., India, Analar grade sample(E-Merck) of dye (Crystal violet) was used in the present study. The structure and value for maximum wavelength for adsorption(λmax) are given in scheme-I. The other chemicals and reagents employed in the present work were of Analar grade.

Preparation of Adsorbent Materials

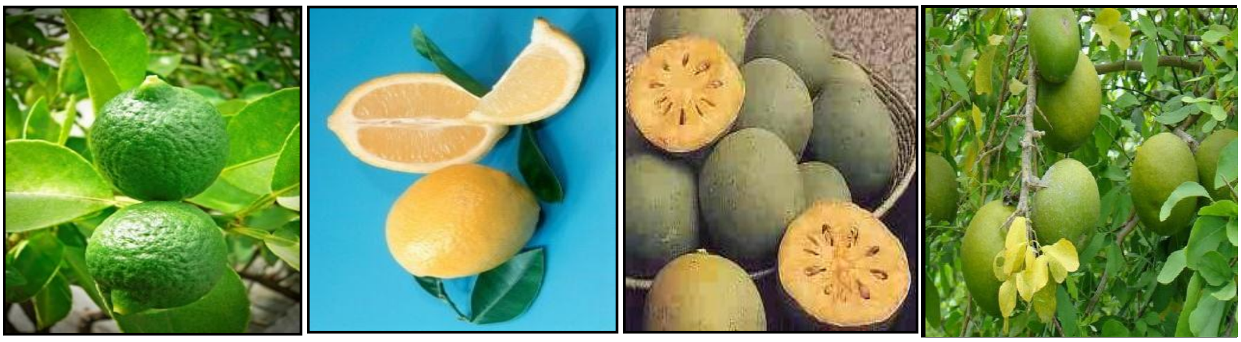
Rutaceae vila carbon

Rutaceae vila Fruit Shell was collected locally and made into small pieces and soaked in water for 6 hours. Then it was dried in open air and then heated to 188^0C in a muffle furnace. Then it was powdered well using mixy. The materials were finally sieved to discrete particle sizes, like 90,120,150 and 250 mic, using sieves of different mesh (particle) size (Jayant Sieve Shaker, India.) The product was treated with 4N HNO_3 and heated for an hour and cooled. After cooling it was washed for several times in order to remove the soluble impurities. Then it was placed in an air oven at the temperature of 110^0C for 5 hours to dry them. Then it was stored in tightly closed bottles.

Vilvam Carbon

Vilvam Fruit Shell was collected and made into small pieces and soaked in water for 6 hours. Then it was dried in open air. It was activated and sieved by using the similar procedure adopted for *Rutaceae vila* carbon and stored in separate bottles. (Figure- 1)

Figure 1: Raw Material of *Rutaceae Vila* and Vilvam Fruit shell



Methods

In present study, the experiments were carried out by employing the batch adsorption experiments. Adsorption of crystal violet (CV) dye on various adsorbents were studied under five different experimental conditions in order to understand the effect of the following experimental parameters. (Figure- 2)

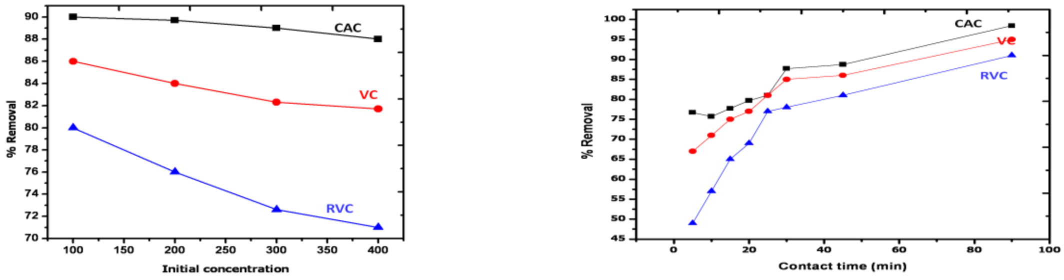
Figure 2: Adsorption of CV using low cost adsorbent

Results and Discussion

Effect of Change of Initial Concentration

To study the effect of initial concentration of CV dye by these adsorbents, the doses of adsorbent were kept constant in all bottles (Dose : CAC: $2gL^{-1}$, IPAC : $10gL^{-1}$) and different initial concentration were maintained (range 300-800 ppm for CAC and 100-800 ppm for IPACs). The bottles were shaken for 30 minutes in a mechanical shaker and the optical density of the filtrate was measured using the Spectro Photometer. The effect of initial concentration of crystal violet dye and the percentage removal of dye by various adsorbents are presented in (Figure- 3 (a)).

Figure 3: (a) Effect of Initial concentration and (b) Effect of contact time on the extent of removal of crystal violet dye by various adsorbents



(a) (b)

The increase in the initial concentration of the adsorbent decreases exponentially with the extent of percentage removal of the dye, it is shown in (Figure- 3(a)).At an optimum initial concentration of adsorbent (300 ppm for CAC, 100 ppm for RVC, 100 ppm for VC), the maximum percentage removal was found. This is due to the fact that after the formation of mono ionic layer at lower concentration over the adsorption surface, any further formation of layer is highly hindered. This is due to the interaction between dye in the surface and in the bulk of the solution.

Effect of Change of Contact Time

All the bottles containing required dose of adsorbent of fixed particle size (90 microns) and 50 ml of dye sample were placed in a mechanical shaker, a stop watch was started simultaneously to note the contact time. The bottles were withdrawn at different time intervals viz, 5,10,15,20,25,30,45,60 and 120 minute and then the solution was filtered. The effect of contact time on the removal of CV dye by adsorption experiments were carried out at optimum initial concentration (300ppm for CAC, 100ppm for RVC, 100ppm for VC).

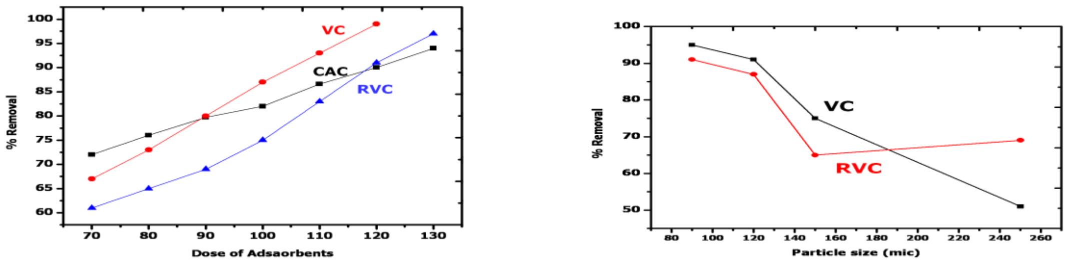
The contact time at which the maximum percentage removal of crystal violet occurs is fixed as the optimum contact time. The decrease in the percentage removal of crystal violet dye, after reaching the optimum contact time, may be due to the desorption process(Figure- 3(b)). The removal of crystal violet dye by adsorption on various low-cost adsorbents was found to be rapid at the initial period of contact time and then become slow and stagnant with increase in contact time.

Effect of Dose of Adsorbent

The experiments were carried out following general procedure for adsorption studies at the equilibrium contact time (30 min) for each adsorbent. The effect of dose of adsorbent (CAC/IPAG), the initial concentration of the dye solution in all the bottles are kept constant and the dose of adsorbent of fixed particle size was varied.

The plots of percentage removal of dye versus dose of adsorbent was found to be exponential for the dye (Figure- 4 (a)) and hence the amount of dye adsorbed on these two adsorbents varied in accordance with the fractional of adsorbent power term of the dose of adsorbents as $(Dose)^n$, Where n=fraction. This suggests that the adsorbed dyes either block the access to internal pores or cause particles to aggregate thereby reducing the availability of active sites. The minimum amount of adsorbent required for maximum removal of CV dye the optimum dose was $2gL^{-1}$ for CAC and $10gL^{-1}$ for IPACS.

Figure 4: (a) Effect of dose of adsorbents and (b) **Effect of particle on the removal of crystal violet dye by adsorption on various adsorbents**



(a) **(b)**

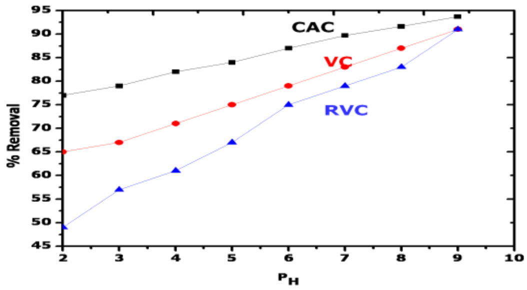
Effect of Particle Size of IPACS

The effect of particle size on the amount of dye adsorbed was studied by varying only the particle size of IPACs as 90,120,150 and 250 mic. CAC was not used since its particle size is uniform and constant at 90mic. The amount of dye adsorbed increases with the decrease in particle size of the adsorbent. This is due to the increase in the availability of surface area with the decrease in particle size.

Effect of pH

The adsorption of crystal violet on these adsorbents namely CAC, RVC and VC (pH : 2-10) with constant optimum initial concentration ($2gL^{-1}$ for CAC and $10gL^{-1}$ for IPACS) of crystal violet, contact time (30 min) and optimum dose of adsorbents were also studied in order to find out the variation on adsorption potential of these adsorbents as a function of pH in adsorbing CV. The pH of the solutions was varied from 2 to 10 by adding the required volume of 0.1N solutions of HCl or NaOH. In each case after the addition of acid or the base pH meter (ELICO, model No. L1-120) using combined electrode (glass saturated calomel electrode system). After shaking the solution for 30 minutes with various adsorbents, the equilibrium concentration of dye was calculated. As a results are (Figure- 5) the adsorption of CV on various adsorbents are found to be highly pH dependent.

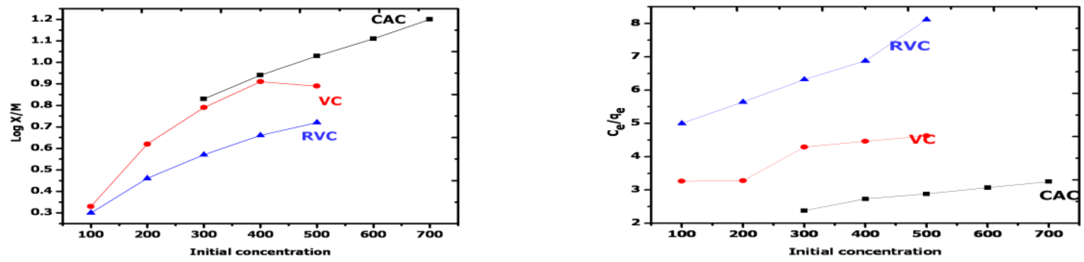
Figure 5: Effect of P_H at Various Adsorbents



Adsorption Isotherms

The study of adsorption isotherms has been of important and significant in water and waste water treatment by the adsorption technique, as they provide an approximate estimation of the adsorption capacity of the absorbent. The equilibrium data for the removal of dye on various adsorbents viz., CAC, RVC and VC (Figure- 6 (a) & (b)) were used in the Freundlich and Langmuir isotherm [31].

Figure 6: (a) & (b) Effect of initial concentration of crystal violet dye on various low-cost adsorbents



(a) **(b)**

The two isotherms plots for all adsorbents are found to be linear, indicating the applicability of these adsorption isotherms for the removal of dye by these adsorbents. Further, the essential characteristic of the Langmuir isotherm and the feasibility of the process is expressed in terms of the dimensionless constant described by the separation factor.

The separation factor RL indicates the feasibility of that process as unfavourable (RL>1), linear (RL=1, favourable (0<RL<C1) and irreversible (RL=0). In the present study, the values of RL being for CAC, RVC and VC indicate that the adsorption for dye CV is favourable.

The adsorption capacity Q_0 of these adsorbents for crystal violet is found to be CAC > VC > RVC

Conclusion

The prepared of Rutaceae vila Fruit Shell carbon (RVC), Vilvam Fruit Shell Carbon (VC) has significantly improve colour adsorption capacity as compared to Commercial Activated Carbon. It was found that colour removal efficiency was achieved maximum at very low dose of 0.06 g for *Rutaceae vila* carbon and 0.05 g of Vilvam Fruit carbon within short time. The adsorption isotherm data was best explained by Langmuir model and the adsorption capacity obtained from Langmuir isotherms for *Rutaceae vila* Fruit Shell carbon (RVC), Vilvam Fruit Shell Carbon (VC) 0.1808 and 0.0647 mg g^{-1} respectively. The result of pH study shows that the adsorbent was effective at normal pH. The *Rutaceae vila* and Vilvam fruit can be used for removal of colour from the waste water and increasing use of agro based bio adsorbent can be seen in coming decade for removal of dyes from wastewater. *Rutaceae vila* and Vilvam fruit have good potential as a low cost adsorbent for improving the effectiveness of waste water treatment.

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