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Lemon Peel Activated Carbon: An Efficient Adsorbent for Removal of Textile Dye from Aqueous Solution

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Abstract:
Lemon Peels impregnated with H_2SO_4 are converted into activated carbon and used as an efficient adsorbent for the rapid adsorption; in turn fast removal of widely used textile dye Acid Red 88 from the aqueous solution. The adsorption of Acid Red 88 dye on Lemon Peel Activated Carbon (LPAC) was studied by considering the parameters viz. effect of adsorption time, concentration of dye solution, temperature, adsorbent dose and pH. Maximum removal of dye from aqueous solution occurs at pH 2.0, adsorbent dose of 0.25 g,dye concentration of 100 mg/L, temperature 303 Kand at equilibrium time of 40 minutes.

Keywords: *Dye, lemon peel, removal.*

I. INTRODUCTION

Dyes are both natural and synthetic organic compounds that impart intense and long-lastingcolour to other materials. A variety of dyes are used to colour textile fabrics. The textile industriesuse large volume of water and produce an extremely large amount of waste water rich in noxious dyes.Dyes show good solubility, so the whole quantity of dye in solution can not be taken up by thefibres[1]. Inefficient textile processing results in 10-15% discharge of dyes directly into the nearby water receiving bodies [2]. The main release of dye wastes occur during dyeing and finishing processes of textile industries [3], [4].

This highly colouredtextile dyes effluent is generally released directly into the nearby drain which ultimately reaches to the river.The discharge of textile dye effluent into the river is one of the most problematic groups of pollutants because it makes the lives aesthetically displeasing and adversely affects the biological processes by impeding penetration of sunlight and may hinder the photosynthesis. The anaerobic breakdown of dyes in the sediments and incomplete microbial degradation often generate amines which are toxic in nature [5].

Dyes cause severe harmful effects on human health like skin irritation, dermatitis, allergic reactions and also provoke carcinogenic reactions.Many dyes cause damage to aquatic flora and fauna. Textile dyeing cause around 25% of industrial fresh water pollution [6].So, removal of dye from water is an essential requirement of these days.

There are enormousmethods in the literature regarding the removalof different pollutants from

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wastewater of the textile industry, few of them are chemical precipitation,oxidation, microbial degradation, filtration, coagulation, membrane separation, flotation, electrochemical treatment, reverse osmosis, ozonation, adsorption, etc.[7] – [22].

Although some present technologiesexhibitwishfulmerits in dye removal buthigh preliminary and operational expenditures restrict their use in dyeing. In contrast, low expenditure technology does not allow a hopeful color removal [23]. The adsorption process is superior in performance over other methods due to its characteristics like absolute dye removal in sludge free and clean process. The commercially available activated carbon is normally used but it is an expensive adsorbent. Hence, this paper suggests acost effective and efficient method of textile dye removal.

The resultsdiscussed in the paperexplain the adsorption studies by lemon peel impregnated withH_2SO_4 which is cost effective adsorbent for efficientlyremoving Acid Red 88 from the dye solution.

II. MATERIALS AND METHODS

A. Lemon Peel

The Lemon Peels were collected from lemon water stall of local market. Lemon peel is a waste obtained after complete lemon juice extraction. Lemon Peels are available from lemon water stall at zero cost in abundant quantity.

B. Acid Red 88

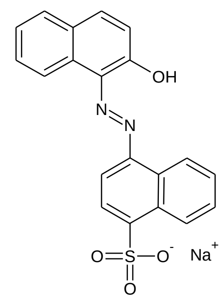

Fig. 1. Chemical structure of Acid Red 88

Table- I: Physical and chemical properties of Acid Red 88 [24]

Parameter	Description
IUPAC NAME	sodium 4-(2-hydroxy-l-napthalenylazo)-naphthalenesulphate
COMMERCIAL NAME	Solid red, 2- Napthol red, Roccelline and Fast red A
CHEMICAL FORMULA	$C_{20}H_{13}N_2NaO_4S$
MOLECULAR WEIGHT	400.38 g.mol^{-1}
PHYSICAL APPEARANCE	Vivid, dark red, opaque, vitreous solid
M. P.	280℃

C. Preparation of Lemon Peel Activated Carbon

The Lemon Peels were collected from lemon water stall of local market and it was washed with water to remove dust and impurities. Sun dried for one day to remove extra water content and then it was dried in oven at 110°C for 24 hours. Lemon Peels were taken in the crucible and concentratedsulphuric acid was added before heating in electric furnace at 100°C for 15 min. Lemon Peels were converted in to Carbon. Lemon Peel Activated Carbon (LPAC) was cooled to ambient temperature, washed with 5N HCl to remove acid soluble impurities and then it was washed repeatedly with distilled water to get rid of acid content and dried. The carbon was milled to produce the powder and sieved with 75 µm mesh, was placed in preheated hot air oven at 100°C for 2 hours to take out moisture.Cooled in a desiccator and stored in dry and air tight bottle and labelled for further experiment.

D. Preparation of Dye Solution:

Acid Red 88 (AR88) dye was heatedfor 2 hours at 100°C in a preheated oven for moisture removal. The moisture free dye was weighed as 1.0 gm and dissolved in distilled water in 1 litre of volumetric flask. This solution was boiled for complete dissolution of dye. Then it was cooled and maintained as 1 litre with distilled water. This stock solution has concentration of 1000 mg/L. It was stored in dry amber bottle,placed in dark and cool place to protect from sun light or UV rays.

III. EXPERIMENTS

- Three batch samples were freshly prepared each having dye concentration of 60, 80 and 100 mg/L in 50 mlfrom the stock. These samples were analyzed by UV-VIS spectrophotometer (Shimadzu, UV1800) for

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the absorbance and wavelength of maximum adsorption (λmax) of dye (Fig. 2).

- 0.2 gm of LPAC was added in dye sample solutions. It was kept for 10 min. at 303K, 313K and 323K with intermittent shaking.
- After 10 minutes the concentration of dye filtrate was determined by spectrophotometer at λmax of 507 nm.
- This procedure was repeated from 10–100minutesat an interval of 10 minutes each to determine the role of adsorption time.
- To understand the role of adsorbent dose, the amounts of absorbentfrom 0.05 – 0.30g at periodical weight difference of 0.05g, added to50 ml 100 mg/L dye solution at equilibrium time of 40 min and analyzed spectrophotometrically.
- For the study of role of pH, the pH values of 100 mg/L concentration of dye solutionwas maintainedat 2.0, 4.0, 6.0, 8.0, 10.0 and 12.0 and shaken with 0.2 g of LPACat equilibrium time of 40 min and analyzed spectrophotometrically.
- The following equation (1) was used to calculate the amount of adsorption capacity[15].

$$q = \frac{C_0 - C_t}{m} V \quad (1)$$

Hence, q, C_0,C_t, m, V, is the adsorption capacity (mg/g), initial concentration of the solution (mg/L), residual concentration of the solution at time t, mass of adsorbent(g) and volume of solution (L) respectively.

IV. RESULTS AND DISCUSSION

A. Absorbance of Standard Dye Solution

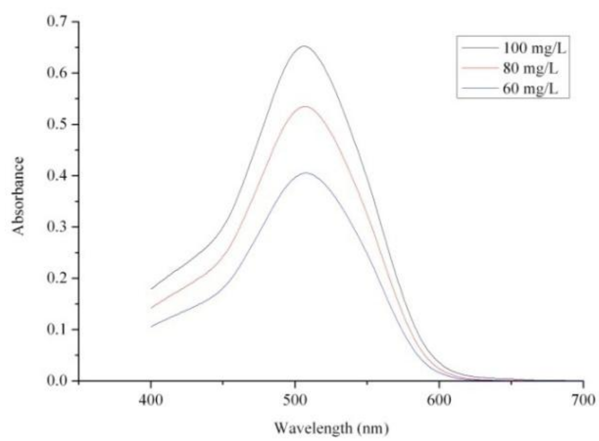

Fig. 2.Plot of Absorbance v/s wavelength (nm) of Standard Dye Solution.

The Fig. 2 shows that Maximum Wavelength of absorption (λmax) of Acid Red 88 dye is 507 nm.

B. Roleof Adsorption Time

For the determination of role of adsorption time, the graphs weredrawn between adsorption capacity of dye and adsorption timeas shown in Fig. 3 – 5. These figuresindicate that the increase in adsorption time for 0.2 g adsorbent also show an increase in adsorption capacity. The result show that in the beginning theadsorption is fast, resulting97% adsorption in first 10 minutes and equilibrium is attained at 40 minutes.

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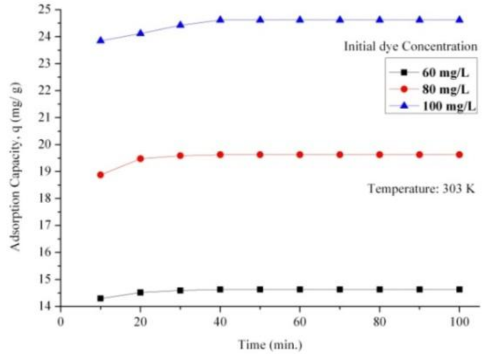

Fig. 3.Time variation plot of adsorption of dye at 303 K

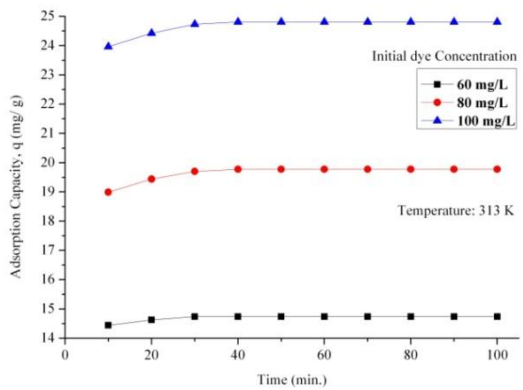

Fig. 4.Time variation plot of adsorption of dye at 313 K

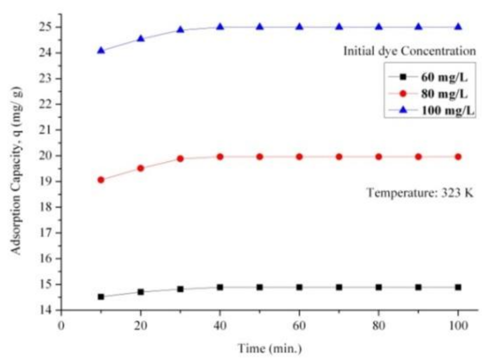

Fig. 5.Time variation plot of adsorption of dye at 323 K

C. Role of Adsorbent Dose

It is an important factor which helps in analyzing adsorbentcapacity for a given concentration of adsorbate. The result is depicted in Table – II and Fig. 6 for the adsorbent. It is clear that with increase in adsorbent dose,increase in adsorption capacity and percentage removal of dye is observed. Maximum adsorption of dye is observed at a dose of 0.25 g of adsorbent.

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Table – II: Role of adsorbent dose on the removal and adsorption of dye using LPAC

Adsorbent Dose (g)	% removal	Adsorption capacity, q (mg/g)
0.05	67.64	16.910
0.1	78.83	19.709
0.15	88.50	22.124
0.2	94.63	23.658
0.25	100.00	25.000
0.3	100.00	25.000

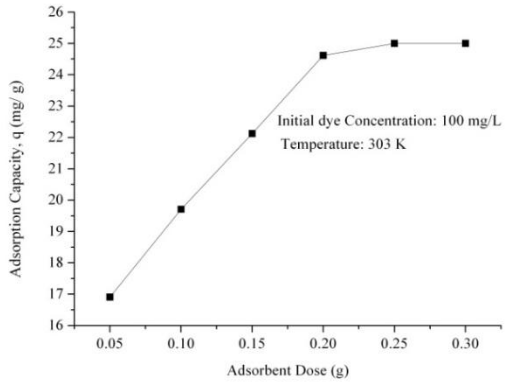

Fig. 6.Roleof adsorbent dose on dye adsorption

D. Role of Concentration

Under identical conditionsof temperature and shaking time, it shows that dye removal by adsorbent is giving good results.

Table – III: Role of concentration on the removal and adsorption of dye usingLPAC

Temperat-ure (K)	Initial Dye Concentra-tion (mg/L)	Amount Adsorbed, q (mg/g)	Percentage Removal	Equilibrium Time (min.)
303	60	14.630	97.53	40
	80	19.626	98.13	
	100	24.617	98.47	
313	60	14.741	98.27	40
	80	19.776	98.88	
	100	24.808	99.23	
323	60	14.889	99.26	40
	80	19.963	99.81	
	100	25.000	100.00	

It is obvious from the results given in Table – III that the degree of adsorption is highly dependent on concentration. For example the percentage removal of dye at temperature 303 K is 97.53, 98.13 and 98.47 at 60, 80 and 100 mg/L dye concentrations respectively. Same trend is observed at 313 K and 323K.

E. Role of Temperature

To understand the role of temperature on adsorption for dye on LPAC were carried out at 303, 313 and 323 K for 60, 80 and 100 mg/L dye concentrations respectively. Fig. 7 – 9 reveals faster adsorption in the beginning, the adsorption of adsorbate is comparatively rapid. However, in the later stages the adsorption process becomes slow and ultimatelya saturation point is achieved. The data obtained at different temperatures suggest that temperature has no effect on the saturation time.However, the extent of adsorption is highly affected as a result of temperature alteration. The results from the Table – III confirm that higher is the temperature better is the dye removal.

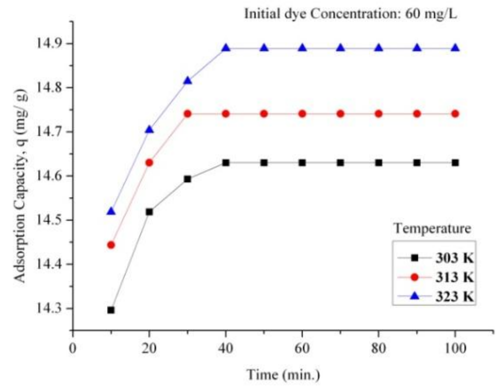

Fig. 7.Role of temperature on adsorption of 60 mg/L dye concentration

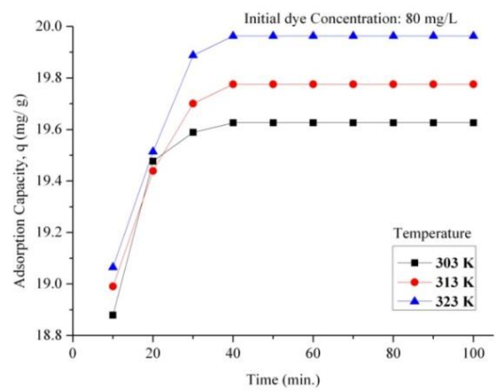

Fig. 8.Role of temperature on adsorption of 80 mg/L dye concentration

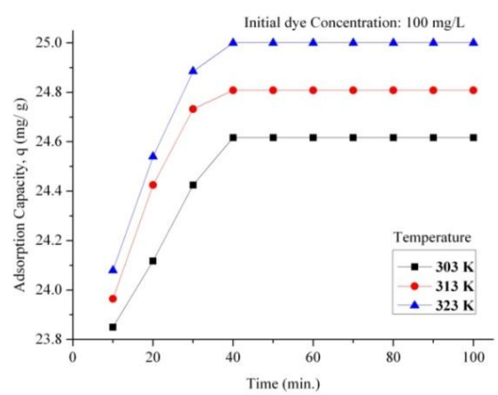

Fig. 9.Role of temperature on adsorption of 100 mg/L dye concentration

F. Role of pH

The role of pH has been investigated and suitable pH where maximum removal of dye is evaluated. During the pH investigation, the concentration of dye solution, temperature and adsorbent particle size was kept constant as 100 mg/L, 303 K and ≤ 75 µm respectively for the system. Adjustment of adsorbate pH is carried out with dilute acid (0.1 N HCl) or dilute base (0.1 N NaOH)and checked with a pH Meter (µSystronic, 361).

Table – IV: Role of pH on the removal and adsorption of dye usingLPAC

Adsorbate solution pH	Percentage removal of dye	Adsorption capacity, q (mg/g)
2	99.23	24.808
4	97.70	24.425
6	97.55	24.387
8	97.09	24.271
10	95.86	23.965
12	83.28	20.821

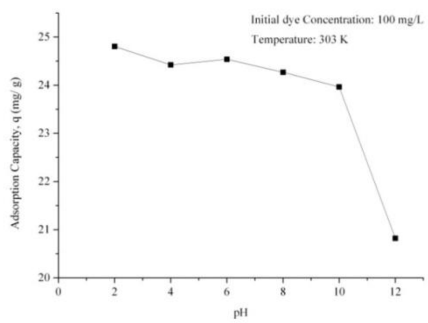

Fig. 10. Role of pH on adsorption of dye

It is clear from the results as recorded in Table – IV and Fig. 10 that dye solution pHgreatly influences removal capacity. The role of functional groups on both; the adsorbent and adsorbate is affected by the variation in pH.

V. CONCLUSION

From the results and discussions of the above studies, the major conclusions are effective removal of dye is carried out by LPAC. Under batch conditions, equilibrium is attained at 40 minutes for LPAC. As concentration increases, percentage removal and amount absorbed increases. This suggests that higher is the concentration, more will bethe number of adsorption sites.LPAC adsorbent shows better adsorption capacity at higher temperature as a result of cleavage of some internal bonds at the edges of the active surface sites of LPAC. Adsorption is directly proportional to the adsorbent dose and in the present study 0.25 g is taken as optimal dose for the adsorbent for maximum adsorption. The pH for maximum adsorption on LPAC is 2.0.Trouble-free availability and aptness of the lemon peel activated carbon make it an adsorbent which can be effectively utilized to remove of Acid Red 88 dye from aqueous solution.

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