De-Colourisation of Textile Dye Effluents using cost-effective Nigella Sativa Seed Waste

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ABSTRACT

The textile industry is one of the major industries contributing to water pollution. The wet processing of textiles involves the usage of a wide variety of chemicals and dyes. This water-intensive process can potentially affect the water bodies by its effluents. The treatment of dye effluents and reusing of the water could be the possible solution to reduce the impact. Adsorption is one of the most common methods used for textile effluent treatment. Various bio-adsorbents are explored to make the adsorption more sustainable. Nigella Sativa (Black cumin) seeds and its oil are having good medicinal value. The seed-waste left after the oil extraction is found to have active components that can be used as an effective bio-adsorbent. The dye removal efficiency of Nigella Sativa seed-waste is investigated under different experimental conditions (varied adsorbent dose, temperature, pH, and contact time) for reactive dyes. The maximum removal efficiency of 91% is obtained at the optimized experimental condition. Thus the study emphasizes that the no-cost Nigella Sativa seed-waste can be used as an effective bio-adsorbent for reactive dye removal from dye effluents.

KEYWORDS: *Nigella Sativa seed-waste, Dye Effluents, Adsorption, Reactive dyes, Bio-adsorbent*

INTRODUCTION

One of the major reasons for the textile industry to become the world's second-largest polluting industry is the toxic chemicals and dyes used in textile processing. The fascinating colors we see in our clothing are got after processing with various toxic dyes that have the potential to create pollution in water systems. Approximately 10-15% of dyes used in the dyeing process are released in the effluent. Nowadays, synthetic dyes are used predominantly. Synthetic dyes are made of organic compounds that are potential enough to cause detrimental effects on the environment as well as humans [1]. The dye effluent treatment grabs attention as the treatment of effluents can lead to reduce the load on the environment and to reuse the huge amount of water that is used in the processing. For the treatment of dye effluents, various physical, chemical, and biological processes are being adopted. Yet, among all these treatments, adsorption, a physical method, seems to be more effective because of its simplicity. Adsorption is a surface phenomenon [2] where a solid substance(adsorbent) can hold the particles on its surface. And hence the equipment and energy involved in the adsorption process are very less when compared with other methods. Various adsorbents are found to be effective in treating textile dye effluents. The most commonly available adsorbents are activated carbon, silica gel, and

zeolite [3]. These adsorbents are synthetic and so the disposal of these adsorbents became tedious. Moreover, these synthetic adsorbents are not cost-effective. These drawbacks of synthetic adsorbents give rise to the search for bio-adsorbents.

Since the use of bio-adsorbent in treating textile effluents can make the process more sustainable, various studies have been made to explore different naturally occurring bio-adsorbents and their efficiency in the removal of textiles dyes. The bio-solid substances are found to have more adsorption sites which facilitate adsorption and also these sites can be modified to increase the binding energy towards the charged pollutants [4]. Some of the known bio-adsorbents are neem sawdust [5], maize cob [6], shale oil dust [7], apple peels [8]. Nigella Sativa (Black cumin) is the herb that belongs to the Ranunculaceae family [9]. Nigella Sativa seed oil has many applications including medicine, spices in meals, food flavoring [10] which leads to increased oil production and generation of seed waste. After oil extraction, the seed still contains active components that can facilitate effective adsorption [11]. This study aims to use Nigella Sativa (Black cumin) seed waste which is obtained as waste from the oil industry as a cost-effective bio-adsorbent for dye removal. Moreover, the experimental conditions such as adsorbent dose, temperature, pH of the solution, and contact time are optimized.

MATERIALS AND METHODS

Nigella sativa seeds are bought from a local store in Coimbatore. The seeds are powdered and crushed to remove oil content. This replicates the seed-waste obtained from the oil industry. Reactive dyes are sourced from Textile Chemical Processing Laboratory, PSG College of Technology, Coimbatore. The standard dye solution is prepared by dissolving 10 mg of reactive dye in 100 mL of water to achieve a concentration of 0.1 g/L. The other known solutions that are used for Beer-Lambert's plot are prepared from the standard solution using the dilution method. The experiments are done sequentially using the result of one in the subsequent experiment. Table I shows the condition of each experiment.

The absorbance values of the treated and untreated solutions are found using a spectrophotometer and the absorbance value is used to find the concentration using Beer-Lambert's law [12]. The equation (1) is used for finding the removal efficiency [13].

$$\text{Removal efficiency (\%)} = \frac{(C_o - C_e)}{C_o} \times 100 \quad - (1)$$

Table I Experimental Conditions

Exp	Conditions	Outcome
1	Adsorbent Dose: 1%, 2%, 3%, 4%, 5%	Optimum Adsorbent Dose
	pH: 5	
	Temp.: Room Temp.	
	Contact time: 24 hrs	
2	Adsorbent Dose: Optimum	Optimum pH
	pH: 5, 7, 10	
	Temp.: Room Temp.	
	Contact time: 24 hrs	
3	Adsorbent Dose: Optimum	Optimum Temp.
	pH: Optimum	
	Temp.: 15°C, 25°C, 40°C	
	Contact time: 24 hrs	
4	Adsorbent Dose: Optimum	Optimum Contact Time
	pH: Optimum	
	Temp.: Optimum	
	Contact time: 12 hrs, 24 hrs, 36 hrs	

The color strength of the treated solutions is also measured by the method using the light reflectance technique. Chroma (psychometric chroma) values were calculated using the following equation [14]:

$$C_{(ab)}* = (a^2 + b^2)^{1/2}, \ \Delta C* = C*_{1(ab)} - C*_{2(ab)} - (2)$$

where $C*_{1(ab)}$ is the chroma value for the standard sample and $C*_{2(ab)}$ is the chroma value for the produced sample.

RESULTS AND DISCUSSION

A. Beer Lambert's Plot

The Beer Lambert's graph was plotted between the absorbance and concentration of 10 known solutions of different concentrations. A linear equation can be developed using the relationship between the absorbance value and the solution concentration. Table II shows the concentration of known solutions and their corresponding absorbance values measured using the spectrophotometer.

Table II Absorbance Values of Known Solutions

S.no	Concentration of dye in g/L	Absorbance Value
1.	0.005	0.086
2.	0.00625	0.090
3.	0.007	0.096
4.	0.008	0.1
5.	0.01	0.11
6.	0.0125	0.121
7.	0.016	0.143
8.	0.025	0.185
9.	0.05	0.323
10.	0.1	0.528

Here, the corresponding linear equation is $y = 4.737x + 0.064$ where y is the absorbance value and x is the concentration of the solution in g/L. With the help of the equation, dye concentrations of the sample solutions after treating with Nigella Sativa in the experiments are calculated. Fig. 1 shows the Beer Lambert's Plot.
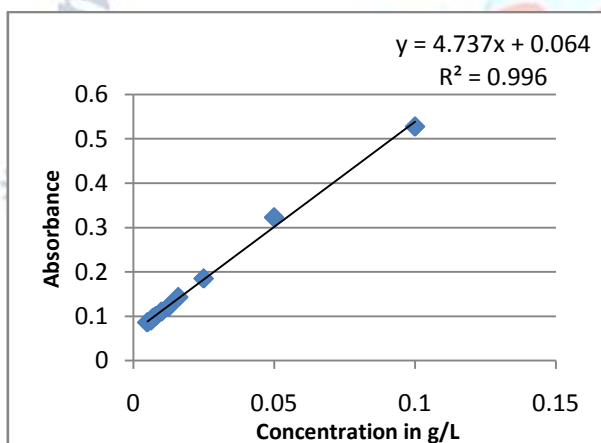

$$y = 4.737x + 0.064$$
$$R^2 = 0.996$$

Fig. 1 Beer Lambert's Plot

B. Effect of Adsorbent Dose

The effect of adsorbent dose on the removal efficiency of the reactive dye on Nigella Sativa seed cake was investigated. The removal efficiency significantly varied with the adsorbent dose. The removal efficiency increases with an increase in adsorbent dose. The adsorption increases from 0.80 mg/g to 1.66 mg/g as increasing the adsorbent concentration from 1 g/L to 5 g/L. A similar effect was observed in the study of adsorption of Crystal Violet, Methylene Blue, Malachite Green, and Rhodamine B dyes by neem sawdust [5]. The increase in the active adsorption sites with increased adsorbent causes more adsorption. Fig. 2 shows the effect of adsorbent dose on the removal efficiency.
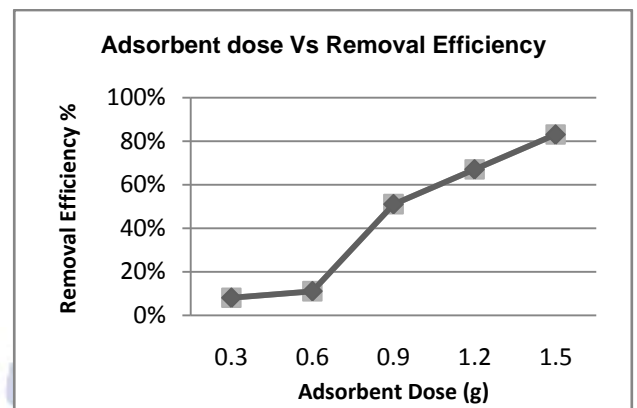

Fig. 2 Effect of Adsorbent dose

The chroma values of the treated and untreated solution also show that with increasing adsorbent dose, the color strength gets reduced. The chroma values of treated samples are shown in Table III.

C. Effect of pH

The investigation of the effect of pH on the adsorption level has shown that the adsorption level increases at acidic pH. The adsorption decreases from 1.66 mg/g to 0.01 mg/g when the pH is changed from 5 to 10. In acidic pH, the solution will be dominated by positively charged particles. Reactive dyes being anionic can easily get attracted to the adsorbent at acidic pH. This result is following the result of the study on adsorption of methylene blue using apple peels where adsorption is effective in basic pH which is attributed to the cationic nature of methylene blue [8]. Fig. 3 shows the effect of pH on the removal efficiency.
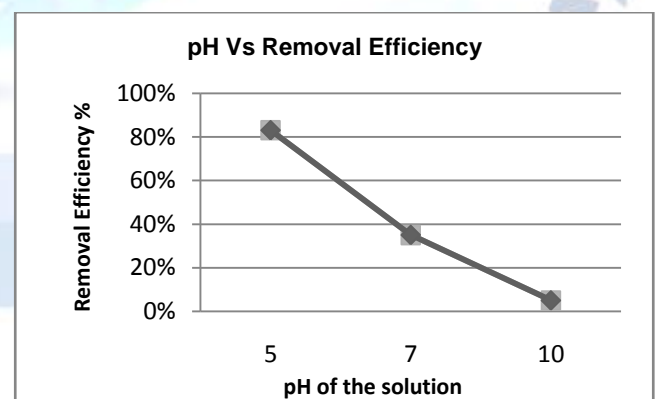

Fig. 3 Effect of pH

The chroma value also gets increased from 10.186 to 15.723 while increasing the pH from 5 to 10. Thus, acidic pH will be effective for the removal of reactive dyes using Nigella Sativa seed-waste.

D. Effect of Temperature

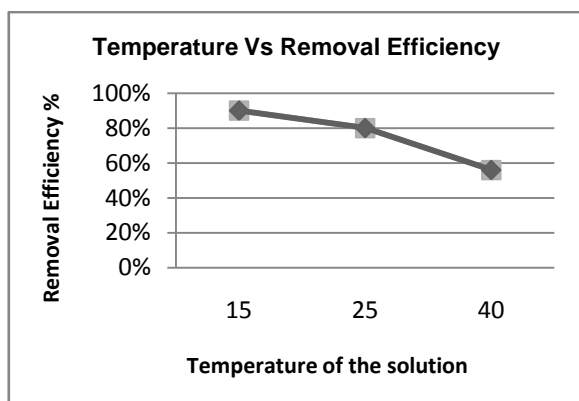The variation in the temperature shows a significant difference in the adsorption level and so the removal efficiency.

Fig. 4 Effect of Temperature

The increased removal efficiency is noted at a lower temperature. The adsorption of reactive dyes increased from 1.12 mg/g to 1.80 mg/g when the temperature is decreased from 40°C to 15°C. At higher temperatures, the solubility of the adsorbent gets increased which in turn increases the energy of the particles. This leads to the desorption of the adsorbate from the adsorbent.

The decrease in the chroma values with increased temperature shows that the color strength can be reduced more at the lower temperature. The chroma values of the solutions treated at different temperatures are summarized in Table III.

Table III Removal efficiency and chroma values in different experimental conditions

Experiment	Adsorbent Dose	pH	Temperature	Contact Time (hrs)	Removal Efficiency %	Chroma Value
1	1%	5	Room Temp	24	8	19.36
	2%	5	Room Temp	24	11	17.65
	3%	5	Room Temp	24	51	14.98
	4%	5	Room Temp	24	67	11.72
	5%	5	Room Temp	24	83	10.19
2	5%	5	Room Temp	24	83	10.19
	5%	7	Room Temp	24	35	13.22
	5%	10	Room Temp	24	5	15.72
3	5%	5	15°C	24	90	9.99
	5%	5	25°C	24	80	10.23
	5%	5	40°C	24	56	11.21
4	5%	5	15°C	12	88	10.03
	5%	5	15°C	24	90	9.92
	5%	5	15°C	36	91	9.59

E. Effect of Contact Time

The contact time has no significant effect on the adsorption. Though adsorption increases with an increase in contact time, the difference is not significant. The adsorption stops when all the active sites get occupied by the adsorbate and there will be no more adsorbent even the process is carried out for a longer time. Fig. 5 shows the effect of the contact time of adsorption. The chroma values of samples treated for the different duration shown in table 3 are also not varied significantly. This again confirms that there is no significant change in color strength.
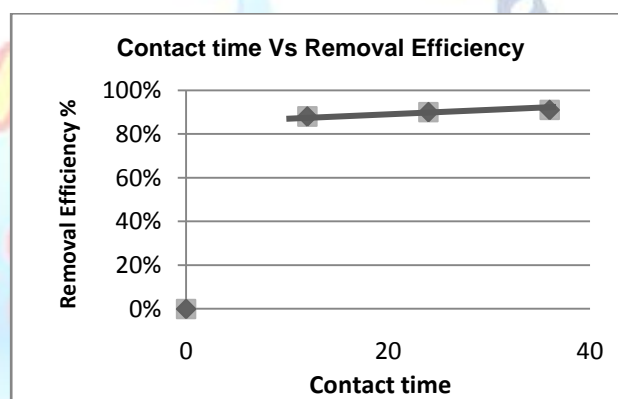

Fig. 5 Effect of Contact Time

Table IV The comparison of Nigella Sativa Seed-waste with other bio-adsorbents for reactive dye removal

Bio-Adsorbent	Max. Removal Efficiency	Reference
Nigella Sativa Seed-waste	91%	This study
Aman Husk	96%	[15]
Cotton dust	98.5%	[16]
Kenaf Core Fiber	99.65%	[17]

CONCLUSION

It has been described that the Nigella Sativa (Black Cumin) seed-waste can be used as a potential bio-adsorbent for the removal of reactive dyes from the textile dye effluents. With the studied experimental conditions, the maximum removal efficiency of 91% is achieved. The investigation of different experimental conditions has shown that

the increased adsorbent dose, acidic pH, lower temperature favors the adsorption of reactive dyes using Nigella sativa seed-waste. Though the contact time has no significant effect on the adsorption, it can affect the processing time. Hence, further study has to be made on the effect of contact time to find the minimum time at which the adsorption can be maximum. This would reduce the processing time.

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