Research Article

A Study of Adsorption of an Organic Colouring Matter on Powdered Natural Plant Material

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Abstract

The present paper describes the study of the removal of an organic colouring matter (Astrazon Brilliant Red 4G) (ABR) from the solution by the adsorbent prepared from wheat straw. To measure the efficiency of adsorption, different parameters like effect of pH, effect of initial dye concentration and effect of adsorbent amount with respect to time were studied. Spectrophotometric technique was used for the measurement of amount of dyes before and after adsorption process. The Langmuir adsorption isotherm model and Freundlich adsorption isotherm model were studied for this adsorption. The study reveals that wheat straw powder (WSP) can be used as an efficient adsorbent for the removal of ABR.

***Key Words*:** Adsorption; Environmental Pollution; Isotherms; Organic Colouring Matter; Removal.

Introduction

Colour is an important feature of beauty. Colourants add colour to life and make life as fine-looking as rainbow. Hence, the demand for colouring matter has experienced phenomenal growth in the past some decades and the application of these dyes has incessantly increased in many industries. Industries like textile, rubber, drug, paper, plastic, cosmetic, food and beverages use dye to colour their products. These coloured organic substances are common water pollutants and they are found in different quantities in industrial waste water. This highly coloured water is discharged into nearby land, river or sea. Even at very low concentration, their presence in water is unquestionably visible and detrimental. Al-Ahmary (2013), Malik and Taneja (1994), Marmangne and Coste (1996), Perkowski and Kos (2003), Rosario et al. (2002) indicated that due to complex aromatic structures, dyes are difficult to degrade and tend to persist in the environment and create severe water quality and public health problems. This contaminated water affects the flora and fauna of the related region. As a result, the environmental issues about the removal of these pollutants are gaining much more attention in recent years.

Conventional technologies employed for eliminating dye from industrial effluents or coloured water includes coagulation, chemical oxidation and biological treatment. However, these processes are very pricey. The dyes from aqueous medium can be efficiently removed by adsorption process which is a surface phenomenon. Dai (1998), Kannan and Sundram (2001) and Karaca et al. (2008) indicated in their work that a well known adsorbent, activated carbon can be prepared from carbonaceous material. As activated carbon is highly porous, it is a superb adsorbent but is very expensive. This has led to further research for the cheaper replacement of adsorbent material.

Extensive research has been directed to the investigation of low cost materials as viable substitutes for activated carbon. These materials include palm fruit bunch (Nassar, 1997), cellulose based waste (Annadurai and Juang, 2002), compost adsorbent (Lo Stuart and William, 2003), orange peel (Rajeshwari et al. (2003), beech saw dust (Bat Zias and Sindiras, 2004), peanut hull (Gong et al., 2005), rice husk (Ola et al., 2005), wheat bran carbon (Ozer and Dursun, 2007), ginger waste (Ahmad and Kumar, 2008), peach nut shells (Memon et al., 2009), fruit shell of Limonia Acidissima, etc. (Torane et al., 2010).

To find efficient and environmentally friendly adsorbents for the removal of various dyes from aqueous medium is a work of immense importance to diminish the black dimension of industrialization. Like the other commercial colourants, use of colouring matter like Astrazon brilliant red 4G (ABR) in textile industry creates pollution when untreated used coloured water is discharged. In the present study, as a natural plant material, dry wheat straw powder (WSP) was used for the elimination of organic matter ABR from its aqueous solution.

Materials and Methods

Adsorbate

Astrazon brilliant red 4G (CAS No. 12217-48-0) was used as an adsorbate for the present work. The dye has molecular formula $C_{23}H_{26}N_3Cl$ (molecular weight: 379.93 g/mol). λ_{max} value of ABR in water is 514 nm. The structure of this dye molecule is shown in Figure 1. Experimental solutions of desired concentrations were prepared in distilled water.

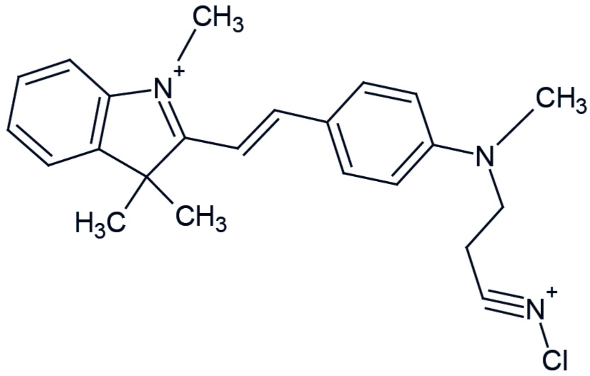

Figure 1 Structure of colouring matter: Astrazon Brilliant Red 4G (ABR)

Adsorbent

Agriculture is the backbone of the Indian economy. Hence, agricultural wastes or agricultural by-products are easily available. India is a country producing and consuming a large amount of wheat. Hence, dry wheat straws are easily available as an agricultural by-product. Dry straws of wheat plants used in the present study were collected from the local farms. They were washed four times with distilled water to remove dust and water soluble impurities, and dried till they became crisp. Then it was sieved in the range of 45-50 mesh (US). The dried straws were further washed with distilled water till the washings were free from turbidity. The powdered material obtained was dried at 105°C for 4-5 hours and placed in a dessicator. This WSP was used as the adsorbent.

Adsorption Experiments

Adsorption of ABR on dry WSP was carried out. The effect of variations in pH values, effect of initial concentration of adsorbate and effect of amount of adsorbent with respect to contact time were studied. Simultaneously, all experiments were conducted with no adsorbent to ensure that adsorption was by wheat straw powder and not by the other factors. The process of adsorption was studied by analyzing adsorption elimination of the dye from the solution. The experimental mixture was stirred on a rotary orbit shaker at 180 rpm. The study was performed according to the methods described in the literature (Changwei et al., 2009; Dae-Hee, 1999; Jusoh et al., 2004; Perineau et al., 1982; Sarkar and Bandyopadhyay, 2010). The parameters of Langmuir adsorption isotherm and Freundlich Adsorption isotherm were also determined.

The adsorption capacity, q_e was calculated by:

$$q_e = V(C_o - C_e) / W$$

where q_e is sorption capacity, V is the volume of the solution and W is the amount of the adsorbent, C_o and C_e are initial and final adsorbate concentrations respectively.

ABR removal percentage (%) = $[(C_o - C_e) / C_o] \times 100$

Results and Discussion

For the determination of effect of pH, study was carried out by taking 400 mg/100ml WSP at (33±1)°C for 150 min. The initial ABR concentration was kept 100 ppm. The results of effect of pH are shown in Figure 2. The results indicate that at high pH, removal of ABR was low, while at lower pH, dye removal efficiency was found high.

For determining effect of the initial dye concentration, the study was performed at fixed adsorbent amount (400mg/100 ml) at room temperature (33±1)°C for 120 min at various initial concentrations of ABR of 50, 100, 150, 200, 250 mg/L. The ABR removal was determined at 20, 40, 60, 80, 100 and 120 min. The results of effect of initial concentration of ABR on adsorption using WSP are shown in Table 1**.** It indicates that as initial concentration of ABR increases from 50 to 200 mg/L, the % removal of ABR increases from 80.10 to 85.01 respectively in the evaluation period of 120 min.

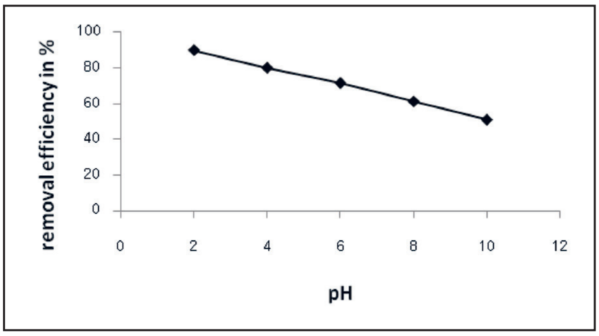

Figure 2 Effect of pH on removal efficiency

The effect of amount of adsorbent on ABR removal was studied by varying the amount of adsorbent at 100, 300, 500, 700, 900 mg/100 ml respectively for 120 min. ABR concentration was kept 100 mg/l with the adsorption time of 120 min. The results of effect of amount of adsorbent on ABR removal are shown in Table 2**.** The results indicate that the percentage of adsorption increases with the increase in amount of adsorbent. As adsorbent dose of WSP increases from 100 mg/100 ml to 900 mg/100 ml, significant increase in % ABR removal was noticed i.e. from 62.11 to 89.14%.

According to the work of Alau et al., (2010) Filipkowska et al., (2002) Kinnlburgh (1986) and Longhinotti et al., (1998), it is clear that the Langmuir and Freundlich adsorption isotherms are most commonly employed models to depict the experimental data of adsorption isotherms. In the present work, the adsorption data was analysed with the help of Langmuir and Freundlich isotherm models. The Langmuir isotherm is given by the following equation:

$$\mathbf{(C_e / q_e) = (C_e / Q) + (1/Qb)}$$

Here, C_e is equilibrium concentration of adsorbate and q_e is the amount of adsorbate adsorbed per unit mass of adsorbent. Q indicates Langmuir constant for the adsorption capacity while b is the Langmuir constant for energy of adsorption capacity. C_e/q_e against C_e were plotted which gave

Table 1 Effect of initial concentration of ABR on adsorption using WSP

Amount of adsorbent (WSP): 400 mg /100 ml, time: 120 min.						
Initial ABR concentration (mg/l)	% of ABR removal with time (min.)					
	20	40	60	80	100	120
50	18.01	39.95	62.85	77.25	80.14	80.10
100	23.32	40.79	55.30	75.10	82.70	82.65
150	25.65	46.26	61.10	75.50	82.95	83.24
200	24.05	44.85	57.80	74.95	83.30	85.01
250	22.88	44.10	60.20	76.14	81.10	82.11

Table 2 Effect of amount of adsorbent on ABR removal

ABR concentration: 100 mg/L, time: 120 min.						
Adsorbent (WSP) dose (mg)	% of ABR removal with time(min.)					
	20	40	60	80	100	120
100	21.35	35.45	42.14	45.67	61.00	62.11
300	25.47	38.80	47.26	70.26	73.84	75.70
500	26.90	60.30	47.95	65.29	84.10	86.15
700	28.05	49.85	48.18	69.87	85.35	88.22
900	34.60	58.90	59.07	73.90	88.01	89.14

linear graph (Y = 0.0285 X + 0.520). The values of Q and b were calculated on the basis of slope and the intercept of the graph.

Baseri, (2012) Hariharasuthan and Nageswara, (2001) Mckay et al., (1984) and Tan et al., (2009) showed in their research work that the essential characteristic of the Langmuir adsorption isotherm can be expressed in the terms of dimensionless equilibrium parameter R_L. It is given by the following equation:

$$\mathbf{R_L = 1/(1 + b\, C_o)}$$

Azraa (2012) showed that the value of R_L indicates the applicability of the chosen isotherm. The R_L indicates the adsorption to be unfavourable ($R_L > 1$), linear ($R_L = 1$), favourable ($0 < R_L < 1$) or irreversible ($R_L = 0$). The value of R_L was obtained 0.1216 which is in the range of 0 to 1. It indicates that the isotherm is favourable for this kind of adsorption. The Langmuir adsorption is shown in Figure 3. Values of related parameters of Langmuir adsorption isotherm model for adsorption of ABR on WSP are as below:

Q = 35.0877, b = 0.0548, correlation coefficient(r) = 0.9996, R_L = 0.1216.

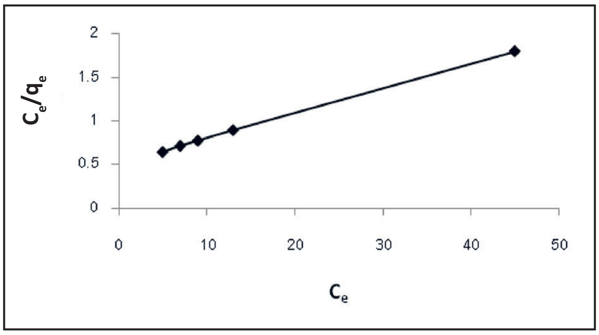

Figure 3 Langmuir isotherm for the adsorption of ABR onto WSP

Freundlich adsorption model can be expressed by the following equation:

$$\mathbf{Log\ q_e = (1/n)\ log\ C_e + log\ K_f}$$

Here, K_f and n are constants. The relation of log q_e and log C_e was plotted results in a linear graph (Y = 0.5261 X + 0.545) indicating the adsorption follows Freundlich adsorption isotherm. The value of exponent 'n' signifies the feasibility of an adsorption model while K_f denotes the ability of the adsorption. The value of 'n' is found 1.9008 which is in the range of 1 to 10 indicating the adsorption model is favourable. The Freundlich adsorption is shown in Figure 4. Values of related parameters of Freundlich adsorption isotherm model for adsorption of ABR on WSP are as below:

K_f = 3.508, correlation coefficient(r) = 0.9933, intercept = 0.5447.

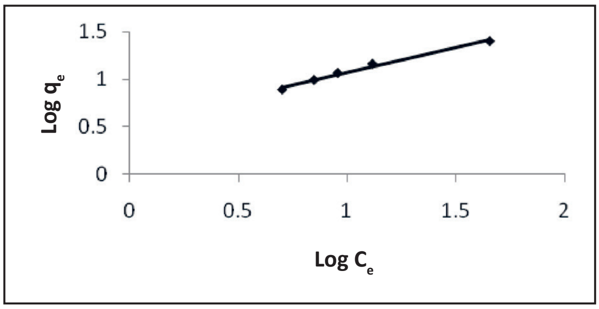

Figure 4 Freundlich isotherm for the adsorption of ABR onto WSP

Conclusion

The amount of ABR adsorbed was found to alter with pH and time. At lower pH, high removal of the colourant from aqeous solution was observed. The present study shows that of effect of initial concentration of ABR on adsorption using WSP indicates that as initial amount of ABR increased from 50 to 200 mg/L, the % removal of ABR reached from 80.10 to 85.01 respectively in the evaluation period of 2 hours. So, it is a good removal of the colourant from the solution. As adsorbent dose of WSP increased from 100 mg/0.1 L to 900 mg/0.1L, significant increase in % ABR removal was noticed i.e. from 62.11 to 89.14% respectively. So, it can be said that the percentage of adsorption increases with the increase in amount of the adsorbent. Thus, as a natural plant material, dry WSP can be used as a good, low cost adsorbent for the removal of the ABR from aqueous solution. Langmuir and Freundlich adsorption models can be applied for the adsorption isotherm of ABR on WSP.

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