Asian Journal of Water, Environment and Pollution, Vol. 20, No. 4 (2023), pp. 93-98.
DOI 10.3233/AJW230056

A Study of the Removal of Pollutants Dyes from Aqueous Solution by Highly Active Low Cost Biosorbents

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Received June 17, 2023; revised and accepted July 8, 2023

Abstract: This research aims to remove the toxic and dangerous Eosin B (EB) dye by using one of the adsorption processes based on environmentally friendly surfaces prepared in a natural way without chemical activation as low-cost agricultural waste, like pomegranate peels, banana peels, clove sticks and eggshells. Several factors were used that affect the adsorption process. These materials have several advantages such as eco-friendly and having a high surface area to enhance the removal of pollutants. The studied parameter includes the contact time of an equilibrium EB dye which was achieved within 60 min, effect of different initial concentrations of EB dye (10-60 mg/L). The concentration of EB dye was found to increase with the adsorption efficiency (Q_e mg/g) while the removal percentage E% decreased, whereas effect of adsorbents dosage was found to increase when the removal percentage (E%) of Eosin B dye increased from 45.55-88.99%, 40.67-82.23% (32.21-77.32%), and (25.34-75.22%). However, the adsorption capacity decreased from 95.66 to 43.43 mg/g, 92.34 to 40.11 mg/g, 90.32 to 37.11mg/g and 91.22-40.3 mg/g when the mass adsorbents of pomegranate peels, banana peels, clove sticks, and egg shells increased from 0.025 to 2 gm in the same order. Also, adsorption isotherms were studied and they obeyed the Freundlich isotherm models.

Key words: Adsorption, Eosin B, dye, egg shells, pomegranate peels, agricultural waste.

Introduction

Nowadays, there is an increasing need to use many materials such as textiles, leather, cosmetics, manufacturing industries, papers, dyeing, and others. All these industries lead to the release of toxic and hazardous wastes into the aquatic environment. Eosin B dye is harmful when ingested or inhaled causing serious injury, skin irritation and life-threatening damage. Direct yellow is usually utilised in the textile and leather industries (Bader et al., 2019; Thakur, 2018; Thakur et al., 2022).

Biosorption is the "cost-effective technique" for removing dyes. Many low-cost agricultural wastes like rice husk, lotus leaves, rejected tea, coconut husk, cotton stalk, peanut husk, egg shells, pomegranate peels banana peel, garlic peel, and orange peel have been used for removal of pollutants (Alqaragully et al., 2015). Agricultural waste in the biosorption system has received wide attention due to its abundance, high

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efficiency and low cost, and one of its most important advantages is its use without any chemical treatment, and reactivation with acid or base for these materials may not be necessary unlike activated carbon (AC). Therefore, the limited use of these agricultural products is still due to their high ability to treat polluted water (Ilgina et al., 2019; Chkirida et al., 2021; Wared and Radia, 2021; Zahraa et al., 2021).

In this work, a good bio-adsorbent was developed by prepared activated carbon which was used to remove EB dye from aqueous solutions. The bio-adsorbent had the advantages of a remarkable activity and adsorption capacity for EB dye. The influences of the initial dye concentration, amount of adsorbent, and contact time on the adsorption process were studied. The adsorption isotherms experiments were carried out in detail.

Experimental Part

A stock solution was prepared by dissolving (0.1 g) Eosin B dye in distilled water 100 mg/L. The calibration curve of EB dye concentration was prepared in several dilutions serial (2-30 mg/L). Absorbance was measured at the λ_{max} EB dye as shown in Figure 1. Adsorption experiments of 0.1 g of adsorbents were performed using a shaker water bath in 100 ml of EB dye of varying concentrations for several time periods at pH (5.4) and temperature (25°C). In addition, the adsorbent dose was examined. The adsorption capacity (Q_e) and percentage (E%) adsorption were estimated from Equations (1, 2).

$$Q_e\left(\frac{mg}{g}\right)=\frac{(Co-Ce)V\,(ml)}{M\,(gm)} \quad (1)$$

$$E\%=\frac{(Co-Ce)}{Co}\times 100 \quad (2)$$

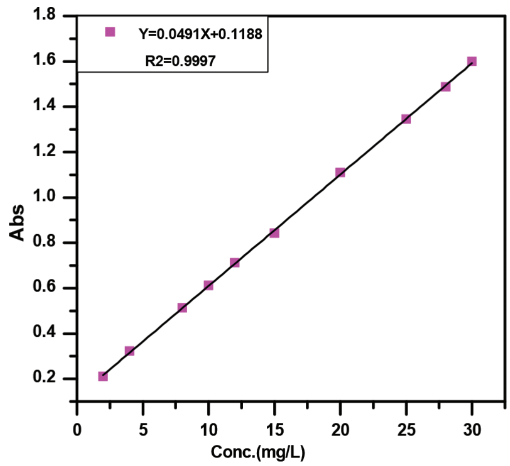

Figure 1: Calibration curve of Eosin B dye.

Preparation of Biosorbent

Fresh of all agricultural waste like Banana peels, pomegranate peels, clove sticks and eggshells are washed with hot water several times to get rid of soluble substances, remove dust also to remove the colour, washed with distilled water and dried at a temperature of 80°C for a period of 12 hours, after that the dried agricultural waste is ground and sieved to particle size 50 nm and kept in airtight containers to obtain the powder used in the experiment.

Results and Discussions

FESEM

Figure 2 (a, c, e and g) shows a FESEM image before the adsorption process, of the eggshells, pomegranate peels, cloves, and banana peels. The lamellar structures were clearly non-porous and with a smooth surface. They contain waves that raise the surfaces of the adsorbent that do not facilitate the diffusion of water into the adsorbent. Figure 2 (b, d, f and h) after the adsorption process shows changes in appearance morphology, for the presence of new asymmetric large particles on the surface. The motive for the high extrusion and roughness of the surface structure is absent before adsorption, and this is evidence of the activation of the free sites of the surface and the occurrence of the adsorption process (Aljeboree et al., 2023; Al-Mashhadani et al., 2021; Thakur et al., 2022).

Effect of Eosin B Dye Concentration

Figure 3 shows the effect of Eosin B dye concentration onto (adsorbent as (a) pomegranate peels, (b) banana peels, (c) clove sticks, (d) eggshells) under the best investigational conditions, i.e., the weight of the surface, temperature of 25°C, pH 4.7. Increasing the concentration of Eosin B dye from 10 to 60 mg/L showed a decrease in the removal percentage (E%), it was found that via raising the dye concentration from 10 to 60 mg/L removal percentage E% decreased from 92.22 to 48.23% (89.54 to 37.44%), 80.01 to 20.45% and 77.01 to 12.45% for all adsorbent as (a) pomegranate peels, (b) banana peels, (c) clove sticks, (d) eggshells, respectively (Mansour et al., 2020; Pashaei-Fakhri et al., 2021).

Effect of Adsorbent Dose

The adsorption capacity is importantly influenced by adsorbent (adsorbent as (a) pomegranate peels, (b) banana peels, (c) clove sticks, (d) eggshells to E% of

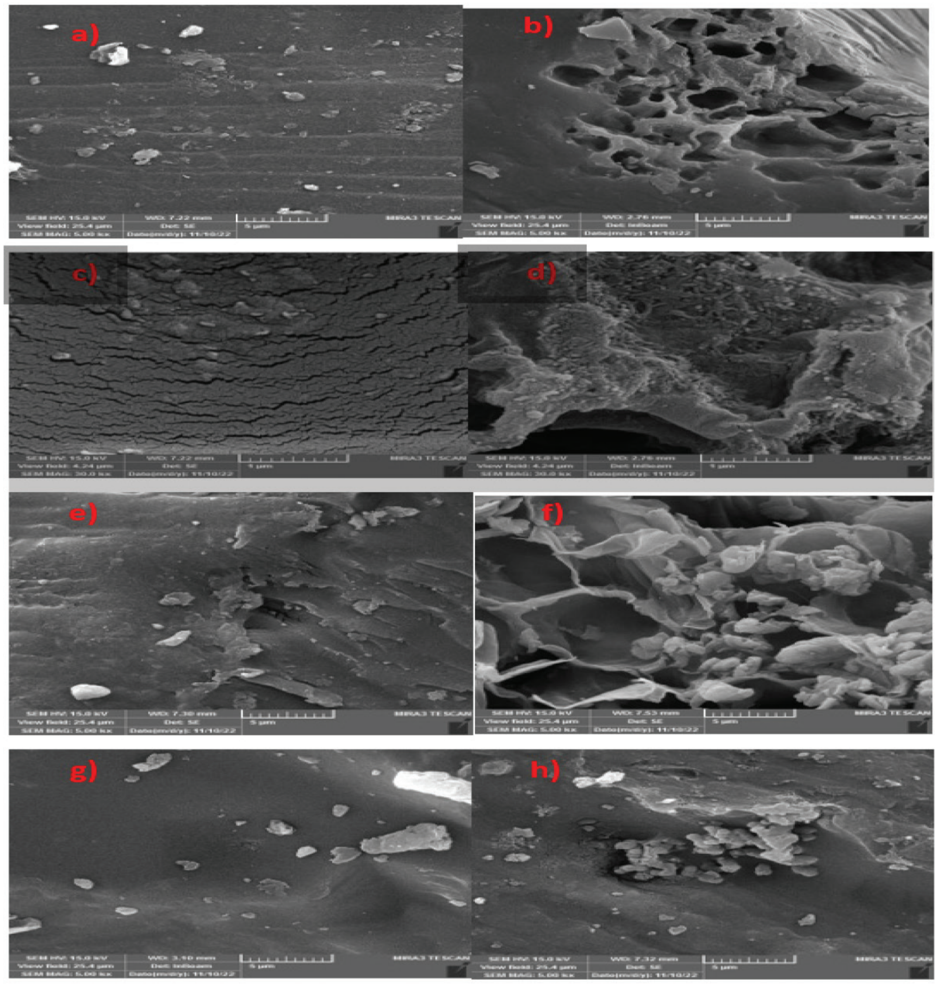

Figure 2: FESEM image of (a,b) banana peels, (c,d) pomegranate peels, (e,f) clove sticks and (g,h) eggshells before, after adsorption.

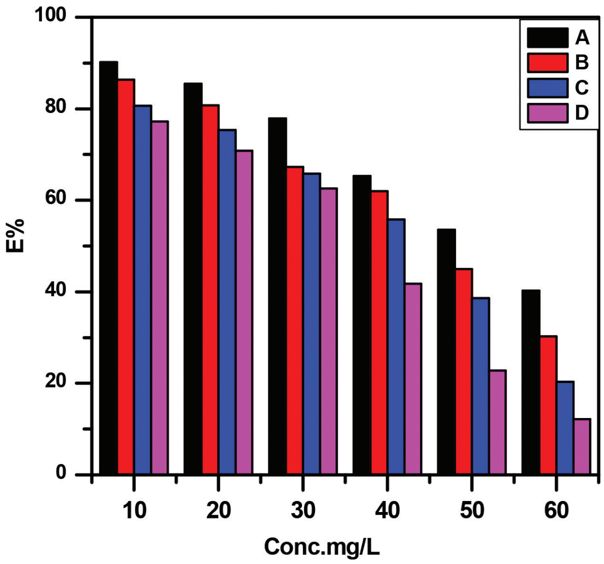

Figure 3: Effect of EB dye concentration on (a) pomegranate peels, (b) banana peels, (c) clove sticks, (d) eggshells.

dye. The amount of Eosin B dye adsorbed by surface was studied of adsorbent weight (0.05-0.2 g/100 mL) at a concentration of dye 30 mg L^{-1} for 60 minutes as shown in Figure 4. The percentage removal E% of Eosin B dye raised from 45.55 to 88.99%, 40.67 to 82.23%, 32.21-77.32%, and 25.34-75.22%, when increasing mass adsorbents from 0.025 to 0.2 gm (Aljeboree et al., 2019; Pakdel et al., 2022). while the adsorption efficiency of Eosin B dye decrease when the mass of adsorbents rises from 95.66 to 43.43 mg/g, 92.34 to 40.11 mg/g, 90.32 to 37.11 mg/g and 91.22-40.3 mg/g. The better adsorption capacity of Eosin B dye was found at a mass dosage of 0.1 g, where the best adsorption capacity (Q_e = 95.66 mg/g), that is because the increased in weight adsorbent surface caused to rises the number of effective sites available for adsorption process, as shown in Figure 4 (Dousova et al., 2018; Ilgina et al., 2019).

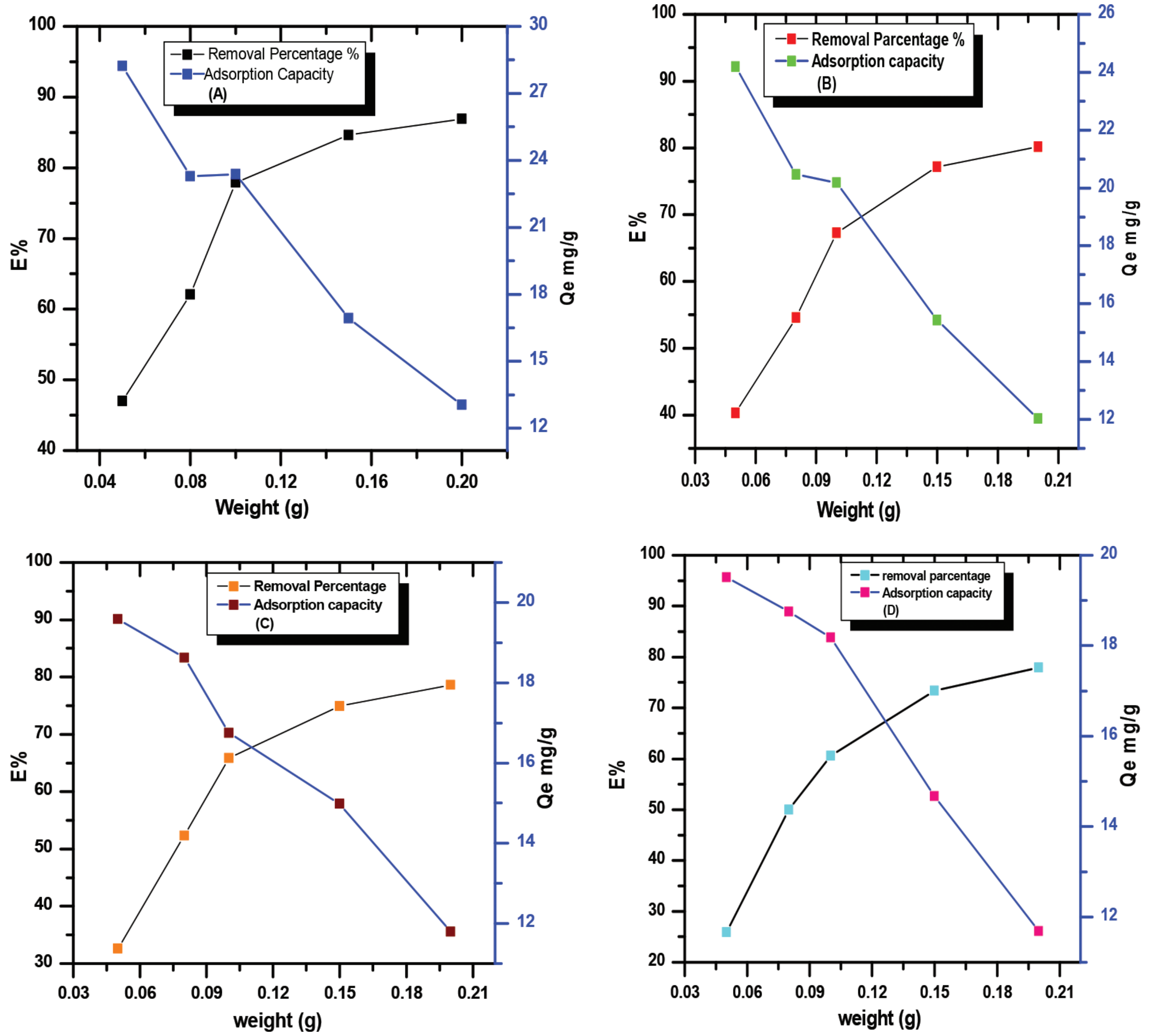

Figure 4: Effect of weight (a) pomegranate peels, (b) banana peels, (c) clove sticks, and (d) eggshells.

Adsorption Isotherm

To give details on the adsorption capacity of the biosorbent, the equilibrium investigational data were studied to confirm compliance with the equations model of Langmuir isotherm and Freundlich isotherm (Gamoudi and Srasra, 2019; Powers, 2003).

Freundlich Isotherm is an experiential equation based on adsorption onto the heterogeneous surface as calculated in Equation (3)

$$Q_e = k_f C_e^{\frac{1}{n}} \tag{3}$$

Langmuir Isotherm is used for the adsorption of a solute from solution as an adsorption monolayer on a surface taking a number finite of identical sites (Orta et al., 2019). The model is setup on different essential assumptions: (i) the sorption occurs at set sites with homogeneous adsorbent; (ii) when the site is occupied by a dye molecule; (iii) the adsorbent (at equilibrium) has ability limited for the adsorbate; (iv) a total of sites are congruous and energetically identical. Equation 4 shows a non-linear equation of isotherm Langmuir that is used as follows:

$$Q_e = \frac{Q_m K_L C_e}{1 + KL\, C_e} \tag{4}$$

The K_F values and (R^2) found from Freundlich models appear in (Table 1). The adsorption of dye better fitted to Freundlich isotherm with the best R^2 = 0.9877 comparison with Langmuir isotherm (Chayid and Ahmed, 2019; Jawad et al., 2021), the Freundlich

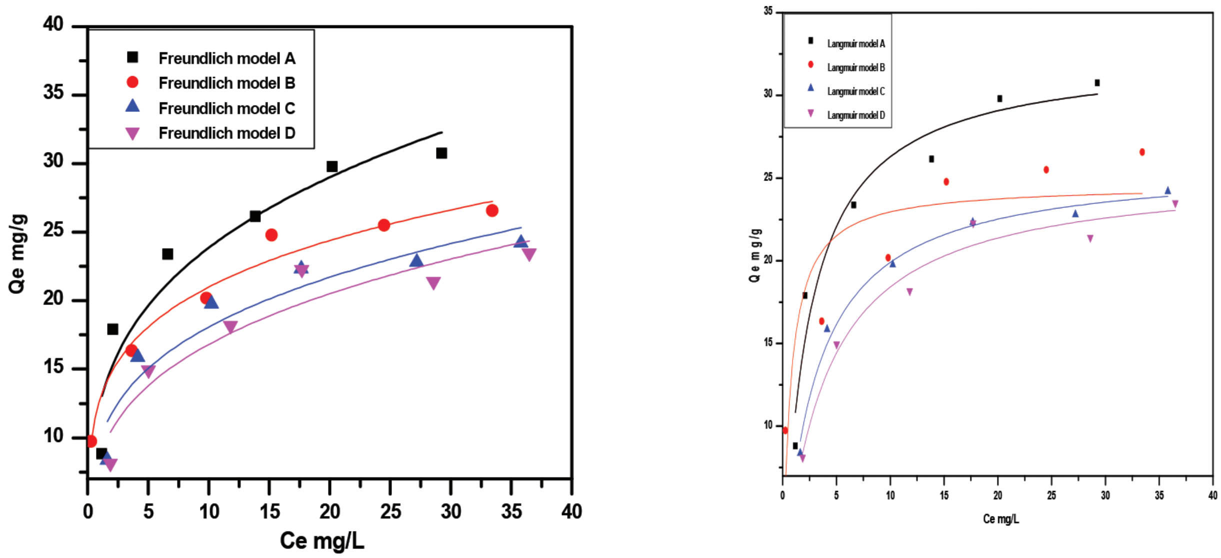

Figure 5: Adsorption isotherm two model Freundlich and Langmuir Isotherm for (a) pomegranate peels, (B) banana peels, (c) clove sticks, (d) eggshells.

Table 1: Effect of different parameters of isotherm models for the adsorption studying of EB dye onto several surfaces

		Pomegranate peels	*Banana peels*	*Clove sticks*	*Eggshells*
Freundlich	K_f	12.452	12.757	9.835	8.693
	1/n	0.288	0.217	0.2643	0.286
	R^2	0.9989	0.9788	0.9888	0.9998
Langmuir	q_m(mg/g)	32.507	24.588	25.916	25.468
	K_L (L/mg)	0.4222	1.397	0.3309	0.2621
	R^2	0.846	0.8377	0.9081	0.966

isotherm has exhibited a better fitted to the adsorption data than the Langmuir isotherm as shown in Figure 5, this may be attributed to multilayer of the surface and nature of the aqueous solution.

Conclusion

It can be concluded that increasing the mass dosage of the surfaces caused the percentage removal % increase and the adsorption capacity decrease, while the higher concentration of EB dye shows the highest adsorption capacity. Adsorption isotherms were studied and it obeyed the good fitting of the Freundlich isotherm model.

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