Egyptian Journal of Chemistry

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Aqueous Solution Decolorization Utilizing Low-Cost Activated Carbon Produced From Agricultural Waste

Basma Esam Jasim *[1] ,Amani Ayad Husain [2], Nibras Abdul-Ameer Aboud [1], Ahmed Mahdi Rheima [3]

[1]*Department of Chemical Industrial, Institute of Technology/Baghdad, Middle Technical University, Iraq.*
[2]*Polymer Research Unit, College of Science, Al-Mustansiriyah University, Baghdad, Iraq.*
[3]*Department of Chemistry, College of Science, Mustansiriyah University, Baghdad, Iraq.*

Abstract

This research assessed the use of agricultural waste as an adsorbent materials to remove dyes from aqueous solutions as a cheap and environmentally friendly adsorbent. Activated carbon (AC) was produced from corn residue and characterized to be nanosized with crystal size 25.83 nm from XRD data and grain size 76.68 nm from FESEM. An anionic dye represent as Eriochrome Black (EBT) used to removed from agueous solution with several adsorption studies were undertaken at varied temperatures, pH levels and adsorbent doses, EBT color molecules are extracted from water and adsorbed as a monolayer on activated carbon,with the highest capacity predicted to be Qe = 23.652mgg^{-1}, the Langmuir and Freundlich models were used to predict adsorption data.In terms of regression coefficients, the experimental data show that the Langmuir fit more than the Freundlich model. Free energy ΔG , enthalpy ΔH and adsorption entropy ΔS were all calculated using isotherms to be 7652.89(J / mol), 8104 (J / mol) and 22.593($J/mol * K$) respectively. Additionally, carried out kinetic studies in order to get the psedo second order rate equation for adsorption. Despite its lower price, advanced carbon has the same adsorption capacity as other commercially available adsorbents.

Keywords: Corn cob, pollution, activated carbon, an anionic dye, Eriochrome Black T (EBT) dye .

1. Introduction

Physical water treatment procedures such as sedimentation and filtration, as well as chemical processes such as coagulation and aeration and microbiological treatment, have been used for degress the damage of pollutation [1] . The adsorption mechanism is a well-developed method of treating physical water. The process of removing impurities from water in order to make it clean is known as adsorption. Adsorbents are the materials a substance used during adsorption process.Adsorbents materials with Low-cost produced using agricultural waste it has shown excellent dye removal abilities in wastewater[2]. Activated carbon is a very common type of adsorbent because activated carbon has a high surface area as nanomaterials [3][4] and a uniform pore size distribution, it is frequently utilized for air pollution treatment and water purification [5][6].The utilization of natural materials or biomass through agricultural waste as raw methods for the development of activated carbon is extremely effective. Utilizing industrial and agricultural waste biomass as a low-cost, ecologically beneficial product. It has been demonstrated that biomass precursor materials for the formation of activated carbon, such as rubber wood, tobacco, almond shell, argania spinosa and fruit clusters, contain lingucello [7], pineapple [8] or terminalia kappa fruit peels.Corn is a popular carbohydrate source that can be substituted for rice. Corn cobs and cornstalk rubbish are thrown and burned as a result of increased demand, seeds are used only as raw materials or food, whilst cornstalk garbage and corn cobs are dumped and burned. Corn waste is reduced by using maize cobs as inexpensive manufacturing raw material for activated carbon. Corn cob has a high proportion of components, including (6%), (36%) and (41%) for lignin, hemicellulose and cellulose respectively demonstrating that could be utilized effectively as a source for (AC) synthesised ; nevertheless, the ash level of corn cobs is relatively low at 1.50 percent. [9] Corn cobs have an (80.50) percent as (carbon

*Corresponding author e-mail: basmaisam@mtu.edu.iq (Basma Esam Jasim)
Receive Date: 26 July 2022, **Revise Date:** 22 August 2022, **Accept Date:** 29 August 2022,
First Publish Date: 28 February 2023
DOI: 10.21608/EJCHEM.2022.152591.6610

content .ash), distinguishing these from a variety of other biomass this is owing to corn cobs having a higher carbon content than other biomass. Azo groups and anthraquinones are the most prevalent chromophores in anionic dyes. Anthraquinone-based dyes are particularly resistant to degradation due to their aromatic rings, and the persistence in wastewaters is growing at the time.[10] [11]. Due to the fact that Eriochrome Black T (EBT) contains an azo group (N=N) and has a limited biodegradability, it is a problem for environmental study [12]. Dyes produced dyeing operations wastewaters can be found in the industrial wastewaters of manufacturing processes such as paints manufacturing, textiles [13] and paper manufacturing. Various techniques used to remove colors from wastewater. Adsorption can be one of the most successful method, and (AC) is the most commonly utilized adsorbent in dye removal. For the treatment of polluted wastewater including several color classes, low-cost agricultural waste adsorbents could be viable alternatives to activated carbon. [14], Due to the toxicity of EBT dye, it was chosen as a representative anionic dye in this investigation[15] [16].

2. Experimental

2.1 Material

All compounds were analytical grade reagents obtained from Sigma-Aldrich and utilized without additional purification.

2.٢ Synthesis activated carbon

(1 gm) corn cobs and (3 gm) sodium hydroxide (weight ratio 1:3) were mixed with molten sodium hydroxide and then placed in a blazing oven at 550 ℃ for an hour. The product was cooled to 25 ℃ then cleaned numerous times with hot water, hydrochloric acid, and distilled water in order to get rid of any remaining NaOH until the desired pH was achieved (7.0). After that, the moist bulk went through a 12-hour drying process at 800 degrees Celsius

3. Results and discussion

3.1 Charctrazition of nano

X-ray diffraction pattern shows the presence of (AC) plane as (002) and (100) at two angles of roughly 21 and 43, as illumistrate in Figure 1. The XRD peak planes of (002) and (100) are relocated to the higher of the angles 2, resulting in a decrease in interlayer spacing. The shifted peak planes are caused by carbon atom rearrangement to a true location in the (AC) structure. [17], and the crystal size was calculated using the scherrer equation [18] to be approximately 25.83 nm .

3.2. **FE-SEM**

As illustrated in Figure 2, FE-SEM was utilized to analyze the morphology of the activated carbon nanoparticles.The treated sample produced quasi-spherical aggregates with a roughly uniform distribution, according to SEM analysis. The as-synthesized nanoparticles' crystalline nature was determined the average nanoparticle size is 76.68 nm due to their small size aggregated together and they are homogeneous with aggregates. These findings are nearly equivalent to those obtained using the model XRD pattern [19].

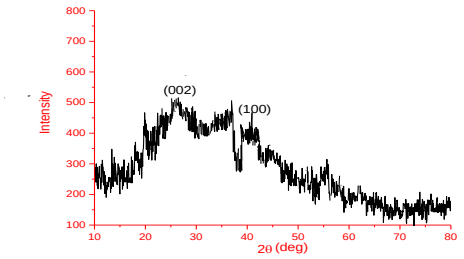

Fig. 1 xrd of activated carbon

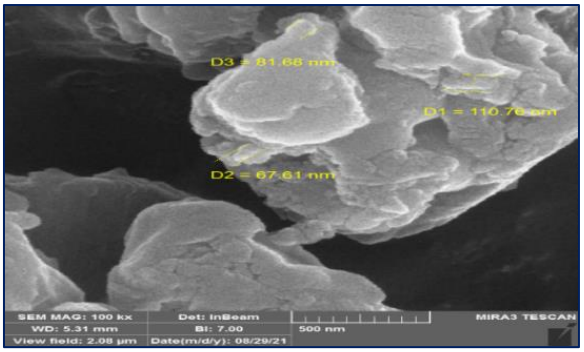

Fig. 2 FE-SEM of activated carbon

3 2. Experiments on adsorption.

In a batch technique, the effects of contact duration (0–160 min), pH (1–10), adsorbent dosage (٠.001-0.1 g), adsorbate concentrations (20-200g/L) and temperature (20 -50 °C) on EBT dye removal were examined .A spectrophotometer was used to measure dye elimination, with 540 nm as the highest absorption wavelength. The percentage of removed and the quantity of dye adsorbed on adsorbent (q_e) were calculated as follows [20] [21]:

$$q_e = \frac{(C_O - C_e)V_{sol}}{M} \qquad \text{------ 1}$$

where q_e is the equilibrium amount of dye adsorbed on the adsorbent at (mg / g), C_0 , C_e denote the beginning and equilibrium dye concentrations (mg/L) in solution, V denotes volume of solution L and M denotes the weight of the adsorbent (g)

Effect of contact time on adsorption:

Figure 3 demonstrates that the equilibrium contact time for EBT dye was attained within 90 minutes after the removal efficiency became constant. For the first 90 minutes, the percentage

elimination for EBT was quick; after that, it progressed at a slower rate until it reached saturation. In general, the adsorption contact time is an important step in understanding how the EBT (adsorbate) approaches the adsorbent surface. Quick removal of adsorbed species is initially facilitated by a large surface area, but the limited number of active sites on the adsorbate's surfaces causes it to become saturated rapidly[22].

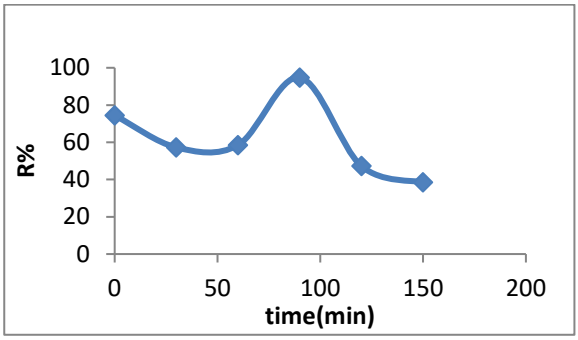

Fig. 3 effects of time on dye adsorption onto activated carbon

Effect of temperature on adsorption:

The temperature effect of dye adsorption upon this activated carbon surface is depicted in Figure 4. Temperature increases reduce the quantity of dye adsorption solutions. This results in an exothermic reaction, exhibiting the absorption and adsorption mechanism. As even the temperature increases, the molecules of diffusion are absorbed by the holes, the rate of diffusion slows, and the link between the adsorbent and the molecules decreases[23] .

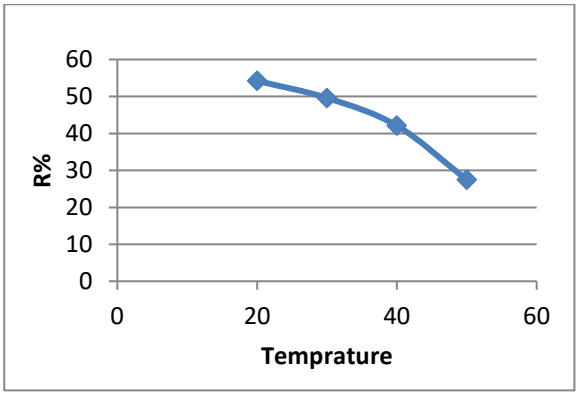

Fig. 4 effects of temperature on dye adsorption onto activated carbon

Effect of weight on adsorption:

The adsorbent efficiency was determined by adding various amounts of AC (0.01g, 0.05g, 0.07g, 0.01 g and 0.15g) to 10 ppm of dye and
shaking the mixture at 298 K. Figure 5 illustrates the relationship between adsorption quantity and mass. Because of the nano size, the adsorption speed is quick, and the rise in dye adsorption increases as the amount of Activated Carbon increases[24].

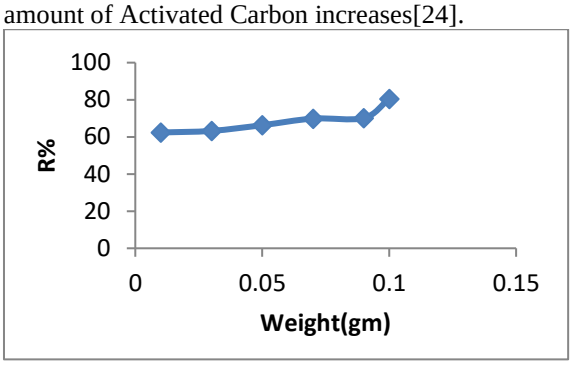

Fig. 5 effects of adsorbent weight on dye adsorption

Effect of temperature PH

The process of adsorption is greatly influenced by the dye solution's pH, notably in terms of adsorption capacity[25]. The adsorption of (EBT) dye is affected by pH, as shown in Figure 6, an initial concentration of EBT dye and the quantity of adsorbent ($0.01gl$) were applied to the (AC). This adsorption capacity increased as the pH of the dye solution increased $(3-6)$ because the dye is negative and the surface is neutral, it is frequently the medium of adsorption associated with the dye's acidic power, and here the dye works inside the acid and neutral media.

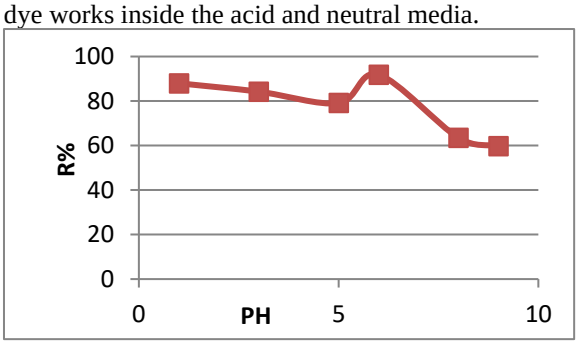

Fig.6 effects of adsorbent PH on dye adsorption

Adsorption isotherms

The fundamental objective of the adsorption study is to compare the adsorption isotherm with the adsorption results to determine how well the adsorption and dyes interact as show in figure 7. This investigation examined both Freundlich and Langmuir models. A linear process of Freundlich adsorption is illustrated by following formula:

$\log(Qe) = \log(kf) + \log(Ce)$ ------2

Freundlich constants kf and n denote adsorption capacity and adsorption intensity, respectively. Freundlich isotherm model adsorption (R^2=0.930).As seen in the following formulation, the data corresponds to the Langmuir adsorption isotherm[26] :

$$\frac{C_e}{Q_e} = \frac{1}{q_{\max}\ KL} + \frac{Ce}{q_{max}} \qquad \text{--------3}$$

The Langmuir constant is KL (mg/L), and the maximal amount of EBT is q max (mg/g). Figure 8 depicts this. The interception has been used to

determine kf, whereas the slope is used to estimate n (0.984). This conclusion is consistent with the fact that chemical adsorption is better fit by Langmuir.

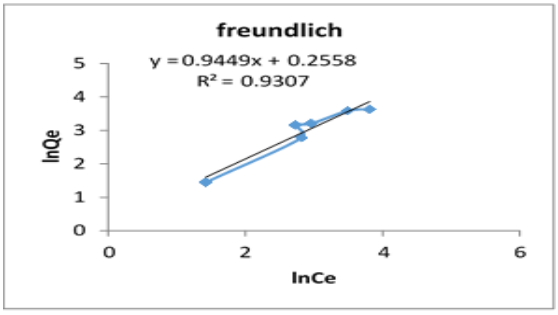

Fig. 7. the Freundlich isotherm.

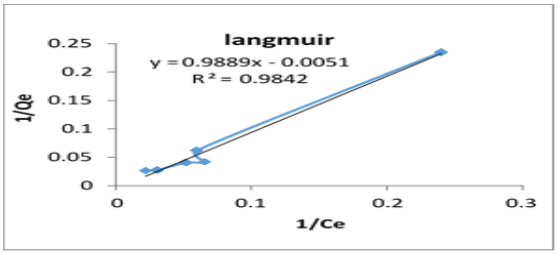

Fig. 8 . The Langmuir isotherm

Thermodynamic

Thermodynamic parameters provide accurate information about adsorbent fluctuations in inherent energy and should be thoroughly investigated. In this study, were utilized to determine the free energy of adsorption ΔG^0, entropy ΔS^0 and enthalpy ΔH^0 to predict the adsorption mechanism[27].

$\ln(ke) = -\Delta HRT + \Delta S\, R$ --------4

$\mathrm{Ke} = Qe \,/\, Ce$ --------5

$\Delta \mathrm{G} = \Delta H - T\,\Delta S$ --------6

R is the constant of gas (8.314 J/mol K), Ke equilibrium constant and T represent temperature in Kelvin k. In Fig.9, a van't Hoff plot between ln K and 1/T is shown

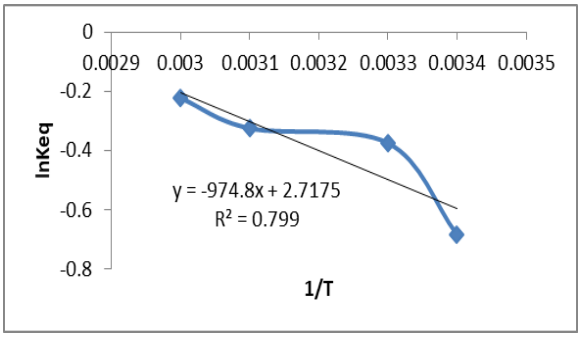

Fig. 9. Van't Hoff plot between ln K and 1/T.

The results presented in table 1 denotes that adsorption of EBT onto AC is an endothermic process. Positive values for ΔG and ΔH imply that an energy barrier exists during the process of adsorption. Positive values of ΔH also indicate that adsorption is endothermic and that physical adsorption is possible. In the case of physical adsorption, positive values of ΔS denotes higher disorder and randomization at the adsorbent's solid solution interface.

Table 1 shows the thermodynamic parameters for EBT dye adsorption onto AC.

ΔH (KJ / mol)	**ΔS (J/mol ∗ *K*)**	**ΔG (KJ / mol)**
8104	22.593	7652.89

Dynamics parameter

The kinetics of dye adsorption on activated carbon surface adsorbents are critical in adsorbent applications .In addition, classical and kinetic modeling were used to illustrate the adsorption data in study described above [28], as follows model of Pseudo-First-Order:

$\ln(qe - qt) = \ln(qe) - k_1\, t$ -------(7)

Where qe (mg. g $^{-1}$) represents the equilibrium adsorption capacity, qt (mg. g $^{-1}$) reflects the quantity of dye adsorbed after time t (min), and k1 represents the pseudo-first-order rate constant (min^{-1}) (A).

The formula for the pseudo-second-order kinetic model is written as [29] ;

$1qt = 1k_2\, qe + tqe$ ---------- (8)

A pseudo-second-order model with a high association factor (R^2 > 0.996) may sufficiently capture the kinetic information and calculated adsorbed amount Qe,cal = 23.625 (mg/g) is extremely very close to the experimental (Qe,exp = 23.256 mg/g), as shown in Fig. 10. (B).

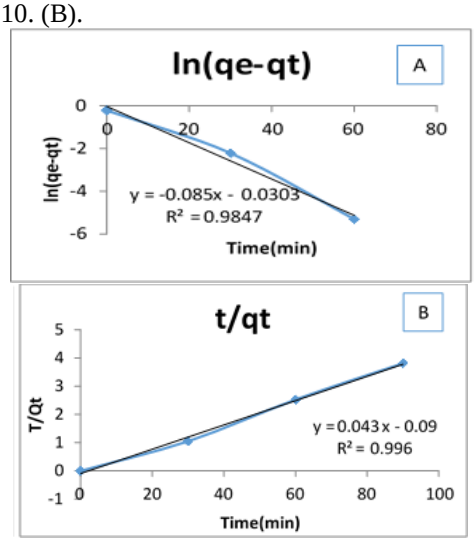

Fig.10 Pseudo-first-order – A, pseudo-second order – B–of EBT adsorption onto activated carbon

4. Conclusions

Corn was used to generate a low-cost, high-efficiency and environmentally friendly adsorbent.

Hazardous waste disposal In terms of activated carbon, Eriochrome Black T (EBT) was employed as a model azo dye to measure the capacity of activated carbon. (EBT) was the elimination of aqueous solution. In the kinetic investigation of EBT adsorption and There was good agreement between the EBT adsorption isotherms and the Langmuir model using the pseudo-second-order model. EBT color molecules are extracted from water and adsorbed as a monolayer on activated carbon,with the highest capacity predicted to be Qe = 23.652mgg^{-1} from the Batch investigations. Both increasing the adsorbent and starting dye concentration increased the Qe value, Prospects For the future we propose using agricultural waste in the production of environmentally friendly materials.

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