

Adsorption of ethyl violet dye in aqueous solution by regenerated spent bleaching earth

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Abstract

The adsorption of basic dye (i.e., ethyl violet or basic violet 4) from aqueous solution onto the regenerated spent bleaching earth (RSBE) was carried out by varying the process parameters such as initial concentration, pH, and temperature. As analytical comparisons, activated bleaching earth (ABE) was also used as adsorbent for the adsorption of the basic dye at various initial concentrations. The experimental results showed that the adsorption process can be well described with the pseudo-second-order reaction model and less fitted by the intra-particle diffusion model. The kinetic parameters of both models obtained in the present work are in line with pore properties of the two adsorbents. According to the equilibrium adsorption capacity from the fitting of pseudo-second-order reaction model, it was further found that the both models of Langmuir and Freundlich appeared to fit well the isotherm data. In addition, the thermodynamic parameters were evaluated based on the pseudo-second-order rate constants, showing that the adsorption of ethyl violet onto the RSBE is endothermic in nature.

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1. Introduction

Activated bleaching earth (ABE), which is industrially activated by acid, has a significant capacity to adsorb coloring matters and undesirable residues from oils, mainly applied in the bleaching of edible oils [1]. However, its waste or spent bleaching earth (SBE) is inevitably generated from edible oil processing. It is noted that SBE not only presents a fire hazard (i.e., spontaneous ignition), but also has an unpleasant odor. In the past, the waste was mostly disposed of to landfills, and partly composted in farms in Taiwan. In order to conservatively utilize this natural resource, Taiwan's Environmental Protection Administration (EPA), in cooperation with the Ministry of Economic Affairs (MOEA), has mandated a regulatory system for its reuse/recycling under the authorization of the newly revised Waste Disposal Act

since 2002 [2]. In our previous studies [3–6], SBE was regenerated by the thermal, chemical, and physical activation methods. The maximum total pore volume of the regenerated SBE (RSBE) obtained by the chemical method was close to $120 \text{ m}^2 \text{ g}^{-1}$, which is equivalent to over 60% of ABE's property based on its total pore volume. The resulting clay adsorbents containing mesopores were further applied for the effective removal of herbicide paraquat from aqueous solution because of the electrostatic attraction between the negatively charged clay particle and the cationic pollutant [4].

Dye effluents, which are often discharged in aqueous effluents from the dyestuff manufacturing, dyeing, and textile industries, may contain chemicals that exhibit toxic effects toward microbial populations and can be toxic and/or carcinogenic to mammalian animal [7]. In Taiwan, the effluent standards have imposed stringent limits on the concentrations of pollutants, chemical oxygen demand (COD) of 100 mg dm^{-3} , biochemical oxygen demand (BOD) of 30 mg dm^{-3} , and true color of 550 in the industrial dis-

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chargers. Conventional methods for the removal of dyes in effluents may be divided into three main categories: physical, chemical, and biological [8,9]. Physical adsorption is generally considered to be an effective method for quickly lowering the concentration of dissolved dyes in an effluent. In this regard, activated carbon has been evaluated extensively for the removal of color resulting from the different classes of dyes and is now the most widely used adsorbent for dyes. However, adsorption using carbon adsorbent still remains an expensive process due to the high cost in the use of activated carbon and the difficulty in the regeneration of spent activated carbon [10]. For this reason, there is growing interest in utilizing low-cost wastes/alternatives to activated carbon as adsorbent [10–12]. However, the unique surface of activated carbon, in contrast to the other adsorbents, is that its surface is nonpolar or only slightly polar, which is not preferable to adsorb or remove polar organic molecules in the fluid streams [13]. Low et al. [14] and Lee et al. [15,16] pointed out that SBE regenerated by carbonization, hexane extraction, and acid treatment could be used as adsorbents for the removal of toxic chemicals in aqueous solution such as basic dye (i.e., basic blue 3, basic blue 9), acid dye (i.e., acid blue 25, acid blue 29) and reactive dye (i.e., reactive blue 2, reactive yellow 2).

Based on the unique properties of RSBE and the scarcity of its utilization as an adsorbent for the removal of basic dye in the literature, the main objectives of this work are to study the feasibility and difference of using ABE and RSBE as adsorbents for the removal of ethyl violet (i.e., basic violet 4) from aqueous solution. RSBE with the optimal properties has been obtained by using the chemical activation as described before [5]. Thus, this work aims at determining the extent of the effects of determining factors such as initial concentration, pH, and temperature on adsorption rate of ethyl violet, and further evaluating the usefulness of pseudo-second-order and intraparticle diffusion models for analyzing the adsorption system between the cationic dye and these clay adsorbents. In addition, this paper was to tentatively evaluate the usefulness of common isotherm models (i.e., Langmuir and Freundlich) based on the equilibrium adsorption capacities from the fittings of the pseudo-second-order model at 25 °C.

2. Methods and methods

2.1. Materials

The basic dye used as adsorbate without any further purification in the present study is ethyl violet (i.e., basic violet 4), which was purchased from Aldrich Chemical Co. (St. Louis, U.S.A.). The identification information and molecular formula of the dye are C.I. 42600 and $C_{31}H_{42}N_3Cl$, respectively. The molecular structure of this dye is shown in Fig. 1. The waste (i.e., SBE) sample was obtained from the Hsiaokang By-products Factory of Taiwan Sugar Co.

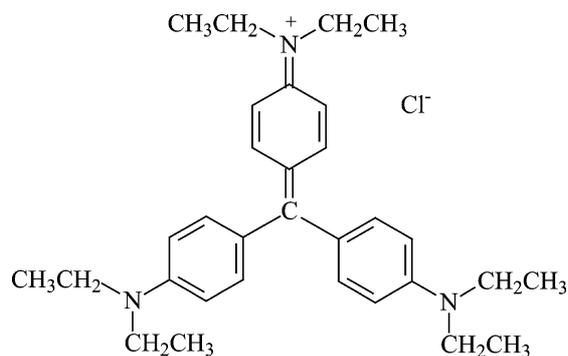


Fig. 1. Molecular structure of ethyl violet used as adsorbate in the present study.

Table 1

Main physical properties of regenerated spent bleaching earth (RSBE) and activated bleaching earth (ABE) used as adsorbents in the present study^a

| Sample | S_{BET}^b ($m^2 g^{-1}$) | V_t^c ($cm^3 g^{-1}$) | ρ_s^d ($g cm^{-3}$) | ρ_p^e ($g cm^{-3}$) | ε_p^f (–) |
|--------|---------------------------------|------------------------------|-------------------------------|-------------------------------|--------------------------|
| ABE | 268 | 0.36 | 2.305 | 1.262 | 0.452 |
| RSBE | 117 | 0.22 | 2.164 | 1.465 | 0.323 |

^a Reference [5].

^b BET surface area.

^c Total pore volume.

^d True density.

^e Particle density, calculated by $\rho_p = 1/[V_t + (1/\rho_s)]$.

^f Particle porosity, computed by $\varepsilon_p = 1 - (\rho_p/\rho_s)$.

(Kaohsiung, Taiwan). The precursor was then impregnated with potassium chloride and finally regenerated in the conditions of constant ramp rate of $10\text{ }^\circ\text{C min}^{-1}$ under N_2 flow of $300\text{ cm}^3\text{ min}^{-1}$, activation temperature of $600\text{ }^\circ\text{C}$, and holding time of 1 h [5]. The main physical properties are given in Table 1 [5]. As experimental comparisons, Table 1 also shows the main physical properties of ABE. Obviously, these adsorbents are characteristic of mesoporous structures, showing that the sample possesses a major peak of pore (slit) widths at about 4.0 nm and a majority of the pores in a broad range at widths of 3.0–20.0 nm [5]. H_2SO_4 and NaOH were used to adjust initial pH value of aqueous solution.

2.2. Batch adsorption studies

The experiments of adsorption kinetics were carried out in a 3-dm³ stirred batch adsorption apparatus with four baffles, as similarly described before [17,18]. The basic dye solutions were prepared with de-ionized water. The effect of agitation speed at 200 and 400 rpm on the adsorption uptake was first tested, showing that it seemed to be negligible. In systems, the effect of the dye concentration of 5–20 mg dm⁻³ on the adsorption uptake of RSBE under the mixing rate of 400 rpm, temperature of 25 °C, pH of 7.0, and dosage of 0.5 g 2.0 dm⁻³ was first investigated. As an analytical reference, the effect of the dye concentration of 10–25 mg dm⁻³ on the adsorption uptake of ABE un-

Table 2
Kinetic parameters for the adsorption of ethyl violet onto RSBE and ABE at various initial concentrations^a

| Adsorbent | Initial concentration (mg dm ⁻³) | Pseudo-second-order | | | Intraparticle diffusion | | |
|-----------|--|--|--|-----------------------|--|--------------------------------|-----------------------|
| | | <i>k</i> (g mg ⁻¹ min ⁻¹) | <i>q_e</i> (mg g ⁻¹) | <i>R</i> ² | <i>k_{dif}</i> (mg min ^{-1/2} g ⁻¹) | <i>C</i> (mg g ⁻¹) | <i>R</i> ² |
| RSBE | 5 | 0.038 | 19.7 | 0.9998 | 1.005 | 10.8 | 0.7653 |
| | 10 | 0.009 | 35.6 | 0.9967 | 1.967 | 16.1 | 0.9365 |
| | 15 | 0.007 | 37.9 | 0.9962 | 2.311 | 15.0 | 0.9417 |
| | 20 | 0.006 | 46.5 | 0.9958 | 2.681 | 19.8 | 0.9313 |
| ABE | 10 | 0.043 | 42.2 | 0.9996 | 7.240 | 19.4 | 0.8988 |
| | 15 | 0.012 | 62.5 | 0.9990 | 7.466 | 24.1 | 0.8703 |
| | 20 | 0.005 | 82.6 | 0.9978 | 7.989 | 25.6 | 0.9154 |
| | 25 | 0.002 | 98.0 | 0.9944 | 6.912 | 28.5 | 0.9455 |

^a Adsorption conditions: adsorbent dosage = 0.5 g 2.0 dm⁻³, agitation rate = 400 rpm, pH 7.0, and temperature = 25 °C.

der the same conditions was also carried out. Then the basic dye with higher adsorption capacity onto RSBE (i.e., at initial concentration 20 mg dm⁻³) was further used to study the variation of adsorption at various temperatures (i.e., 15–45 °C) and pH (i.e., 3–11). The solution sample was taken at a specified time and then filtered with fiber membrane (Cat. No.: A045A025A; ADVANTEC MFS, Inc.). The basic dye concentration analysis of filtrate solution was immediately measured with UV/visible spectrophotometer (Model: U-2001; Hitachi Co., Japan) at 594 nm wavelength. The amount of basic dye adsorbed (*q_t*, mg g⁻¹) was determined as

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

where *C₀* and *C_t* are the initial and liquid-phase concentrations of the basic dye solution at time *t* (mg dm⁻³), respectively, *V* is the volume (ca. 2.0 dm³) of aqueous solution containing basic dye, and *m* is the mass of dry clay adsorbent used (g). In order to evaluate the statistical significance of data in the kinetic experiments, a preliminary experiment was also repeated under identical conditions, showing that the reproducibility of the measurements was within 5% in the adsorption experiments.

3. Results and discussion

3.1. Adsorption kinetics

Due to the fast decrease in residual dye concentration at a short time scale, implying the strong electrostatic interaction between the negatively charged surface and the cationic dye, a simple kinetic analysis of adsorption a pseudo-second-order equation, was used to fit the experimental data as reported before [17,18]. Its linear form can be described in the form

$$\frac{t}{q_t} = \frac{1}{kq_e^2} + \frac{1}{q_e}t, \quad (2)$$

where *k* is the rate constant of pseudo-second-order adsorption (g mg⁻¹ min⁻¹) and *q_e* and *q_t* are the amounts (mg g⁻¹)

of the dye adsorbed at equilibrium and time *t*, respectively. Rate parameters, *k* and *q_e*, can be directly obtained from the intercept and slope of the plot of (*t/q_t*) against *t*. The equilibrium concentration (i.e., *C_e*) can be further calculated from Eq. (1), as the value of *q_e* has been obtained from the fitting of Eq. (2).

An adsorption reaction is said to be intraparticle-diffusion-controlled if the reaction sites are internally located in the porous adsorbents and the external resistance to diffusive transport process is much less than the internal resistance. The intraparticle diffusion model is expressed as [19]

$$q_t = k_{dif}t^{0.5} + C, \quad (3)$$

where *q_t* is as defined in Eq. (2), *k_{dif}* is the intraparticle diffusion rate constant (mg min^{-1/2} g⁻¹), and *C* is the intercept. According to Eq. (3), a plot of *q_t* vs *t*^{0.5} should be a straight line with slope *k_{dif}* and intercept *C*. The term *k_{dif}* is indicative of an enhancement in the rate of adsorption [20]. The value of *C* gives an idea about the boundary layer thickness [19].

3.1.1. Effect of initial dye concentration

The rate of adsorption uptake by different initial ethyl violet concentrations onto RSBE at adsorbent dosage of 0.5 g 2.0 dm⁻³, mixing speed of 400 rpm, pH of 7.0, and temperature of 25.0 °C decreased with increasing time until it gradually approached a plateau due to the continuous decrease in the concentration driving force, as reported before [17,18]. The kinetic data obtained from batch studies have been analyzed by using the pseudo-second-order model. The values of *k* and *q_e* for the basic dye, computed from Eq. (2), are listed in Table 2, from which it will be seen that the kinetic modeling of dye adsorption onto the clay adsorbent well follows this model, with correlation coefficients higher than 0.99 for the entire system. From the results in Table 2, the equilibrium adsorption capacity (i.e., *q_e*) increases as the initial dye concentration (i.e., *C₀*) from 5.0 to 20 mg dm⁻³. Further, it was found that the variations of the rate constant (i.e., *k*) seem to have a decreasing trend with increasing initial dye concentration, which is consistent with studies reported before [21,22]. In addition, Table 2 also shows the

adsorption kinetics of ethyl violet onto ABE at the nearly same conditions. It is clear that the adsorption capacities of the basic dye onto ABE are always much larger than those of the adsorption onto RSBE, which is in line with the pore properties (268 vs 117 $\text{m}^2 \text{g}^{-1}$ and 0.36 vs 0.22 $\text{cm}^3 \text{g}^{-1}$) of the two adsorbents listed in Table 1. The result showed that the adsorption capacity of the adsorbent is dependent on its pore properties, supporting the fact ABE contains more pore space available for the adsorption of ethyl violet dye onto it. The adsorption of ethyl violet onto ABE has been exactly completed at 5, 10, and 30 min under initial concentrations of 10, 15, and 20 mg dm^{-3} , respectively. The situation was very reasonable because the values of the mass transfer coefficient were lower at higher initial concentrations as a result of the increase in equilibrium time with increasing initial concentration.

The adsorption kinetic data was further processed to find rate parameters of the intraparticle diffusion model. The values of k_{dif} at ABE are always larger than those of k_{dif} at RSBE, as listed in Table 2. Clearly, it is again consistent with the data on the pore properties (268 vs 117 $\text{m}^2 \text{g}^{-1}$ and 0.36 vs 0.22 $\text{cm}^3 \text{g}^{-1}$) and q_e in Tables 1 and 2, respectively. The result showed that the k_{dif} value of adsorbent is also dependent on its pore property, supporting the fact ABE possesses more potential for the adsorption of ethyl violet dye onto it because k_{dif} is indicative of an enhancement in the rate of adsorption. From the data on regression coefficients in Table 2, it may be pointed out that the uptake of ethyl violet slightly varies with the half-power of time ($t^{0.5}$). The adsorption kinetic modeling also indicated that the straight line did not pass through the origin, implying that the adsorption system is a rather complex process that involves both boundary layer diffusion and intraparticle diffusion mechanisms [23].

3.1.2. Effect of pH

The effect of initial pH on the rate of basic violet 4 uptake onto RSBE was investigated at an initial concentration of 20 mg dm^{-3} , adsorbent dosage of 0.5 g 2.0 dm^{-3} , agitation speed of 400 rpm, and adsorption temperature of 25 °C. Again, the kinetics of the basic dye adsorption follows this model with regression coefficients of higher than 0.99, as listed in Table 3. Obviously, the adsorption capacity (i.e., q_e) exhibits a typical “bathtub” pattern. Thus, the maximum adsorption capacity of basic violet 4 from aqueous solution takes place at basic condition (pH 11) or acidic condition (pH 3), while the dye adsorption shows a minimum around pH 9. These observations were similar to earlier findings for the adsorption of methylene blue on kaolinite [24]. It is known that the adsorbed amount of cationic dye increases with increasing pH in response to the increasing number of negatively charged sites that are available due to the loss of H^+ from the surface of the clay particle [19,24]. These negative charges in the surface of the clay adsorbent were thus increased with increasing pH, which is parallel to the increase in adsorbed amounts with increasing pH in

Table 3

Kinetic parameters for the adsorption of ethyl violet onto RSBE at various initial pH^a

| Initial pH | k ($\text{g mg}^{-1} \text{min}^{-1}$) | q_e (mg g^{-1}) | Correlation coefficient |
|------------|---|---------------------------------|-------------------------|
| 3.0 | 0.0051 | 63.7 | 0.9933 |
| 5.0 | 0.0066 | 46.9 | 0.9950 |
| 7.0 | 0.0063 | 46.5 | 0.9958 |
| 9.0 | 0.0061 | 44.1 | 0.9947 |
| 10.0 | 0.0071 | 54.6 | 0.9979 |
| 11.0 | 0.0226 | 80.0 | 0.9999 |

^a Adsorption conditions: dosage = 0.5 g 2.0 dm^{-3} , initial concentration = 20 mg dm^{-3} , agitation rate = 400 rpm, and temperature = 25 °C.

Table 4

Kinetic parameters for the adsorption of ethyl violet onto RSBE at various temperatures^a

| Temperature (°C) | k ($\text{g mg}^{-1} \text{min}^{-1}$) | q_e (mg g^{-1}) | R^2 |
|------------------|---|---------------------------------|--------|
| 15 | 0.0045 | 36.1 | 0.9955 |
| 25 | 0.0063 | 46.5 | 0.9958 |
| 35 | 0.0054 | 48.8 | 0.9959 |
| 45 | 0.0038 | 56.5 | 0.9912 |

^a Adsorption conditions: initial concentration = 20 mg dm^{-3} , adsorbent dosage = 0.5 g 2.0 dm^{-3} , agitation rate = 400 rpm, and pH 7.0.

the adsorption system of cationic paraquat and ABE [18]. However, the tendency for increasing adsorption at pH values below 7.0 is difficult to explain. It could be due to the removal of residues left in the pores of RSBE under acidic conditions, resulting in the slight increase of surface area for the adsorption.

3.1.3. Effect of temperature

The variations of q_t vs t at various temperatures of the dye solution under the initial concentration of 20 mg dm^{-3} and pH of 7.0 still confirmed to fit the pseudo-second-order model with high correlation coefficients (> 0.99). The values of model parameters (i.e., k and q_e) for different temperatures have been calculated from Eq. (2) and the results are given in Table 4, revealing that the fitted adsorption capacity at equilibrium (i.e., q_e) increased with increasing temperature. For example, the values of q_e increased from 36.1 mg g^{-1} at 15 °C to 56.5 mg g^{-1} at 45 °C. Furthermore, the values of C_e decreased with increasing temperature. The observations were in line with those observed by Low et al. [14] for carbonized SBE and basic blue 3 and methylene blue (i.e., basic blue 9), by Ghosh and Bhattacharyya [24] for kaolinite and methylene blue, and also by Dogan and Alkan [19] for perlite and methyl violet (i.e., basic violet 1). These results imply that chemisorption mechanism may play an important role for the adsorption of basic dyes on the bleaching earth.

The thermodynamic parameters of the adsorption process are further obtained from the experiments at various temper-

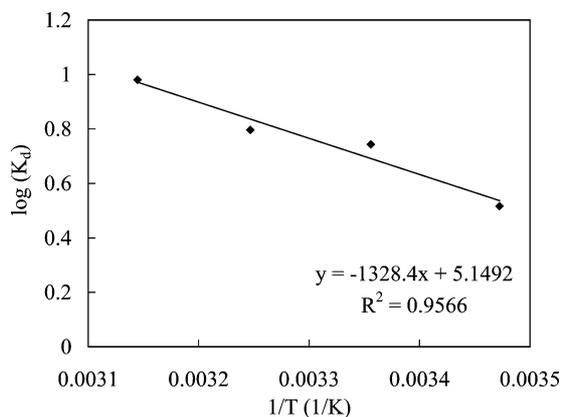


Fig. 2. A plot of $\log K_d$ vs $1/T$ for the adsorption of ethyl violet onto RSBE.

atures using the equations [24,25]

$$\log K_d = \Delta S^0 / (2.303R) - \Delta H^0 / (2.303RT), \quad (4)$$

$$K_d = q_e / C_e, \quad (5)$$

where ΔH^0 and ΔS^0 are the standard enthalpy and entropy for the adsorption process, respectively, R is the ideal gas constant, T is the adsorption temperature, and K_d is the distribution coefficient. Equation (5) corresponds to the linear part of the adsorption isotherm. Using Eq. (4), the values of ΔH^0 and ΔS^0 can be determined from the slope and intercept of the linear plot of $\log K_d$ vs $1/T$, respectively. As shown in Fig. 2, the values of ΔH^0 and ΔS^0 were calculated to be 25.4 kJ mol^{-1} and $98.6 \text{ J mol}^{-1} \text{ K}^{-1}$, respectively. These results reveal that the adsorption of ethyl violet onto the RSBE is endothermic in nature. It was reported that the ranges of ΔH^0 and ΔS^0 for adsorption of methylene blue on kaolinites are $6.0\text{--}13.5 \text{ kJ mol}^{-1}$ and $69.7\text{--}88.2 \text{ J mol}^{-1} \text{ K}^{-1}$, respectively [24]. The endothermic nature of adsorption of methylene blue onto diatomaceous clay was also obtained by Shawabkeh and Tutunji [25], revealing that the values of enthalpy and entropy were calculated to be 6.42 kJ mol^{-1} and $25.2 \text{ J mol}^{-1} \text{ K}^{-1}$, respectively. In the present work the results show that the adsorption of ethyl violet onto the RSBE has a higher potential because of the larger thermodynamic parameters when compared to earlier findings for the adsorption of methylene blue on similar clay adsorbents [24,25].

3.2. Adsorption isotherm

Two common adsorption models have been tested in the present study, Langmuir and Freundlich models [26,27]:

$$\text{Langmuir: } 1/q_e = 1/[K_L q_m C_e] + 1/q_m, \quad (6)$$

$$\text{Freundlich: } q_e = K_F C_e^{1/n}. \quad (7)$$

In Eq. (6), C_e and q_e are the concentration (mg dm^{-3}) and amount (mg g^{-1}) of ethyl violet adsorbed at equilibrium, respectively, K_L is a direct measure of the strength of adsorption herein ($\text{dm}^3 \text{ mg}^{-1}$), and q_m is a constant relating

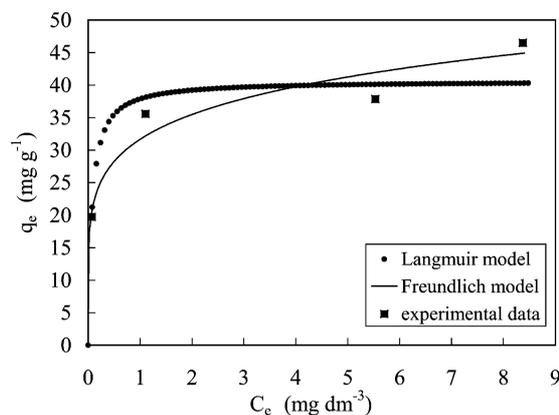


Fig. 3. Isothermal adsorption of ethyl crystal in aqueous solution onto RSBE at 25°C . (Adsorption conditions: dosage = $0.5 \text{ g } 2.0 \text{ dm}^{-3}$, initial concentration = 20 mg dm^{-3} , agitation rate = 400 rpm , and $\text{pH } 7.0$.)

Table 5

Parameters in Langmuir and Freundlich adsorption isotherm models of ethyl violet onto RSBE at 25°C^a

| Langmuir | | Freundlich | | | |
|------------------------|-----------------------------------|------------|--|-------|--------|
| q_m | K_L | R^2 | K_F | $1/n$ | R^2 |
| (mg g^{-1}) | ($\text{dm}^3 \text{ mg}^{-1}$) | | ($\text{mg g}^{-1} (\text{dm}^3 \text{ mg}^{-1})^{1/n}$) | (-) | |
| 40.7 | 13.7 | 0.9671 | 31.7 | 0.164 | 0.9437 |

^a Adsorption conditions: initial concentration = $5\text{--}20 \text{ mg dm}^{-3}$, adsorbent dosage = $0.5 \text{ g } 2 \text{ dm}^{-3}$, agitation speed = 400 rpm , and $\text{pH } 7.0$.

to the surface area occupied by a monolayer of adsorbate, reflecting the adsorption capacity (mg g^{-1}). Based on the data of q_e from the fittings of the pseudo-second-order adsorption rate model, q_m and K_L can be determined from its slope and intercept from a typical plot of $1/q_e$ vs $1/C_e$. In Eq. (7), K_F is a constant for the system, related to the bonding energy. K_F is related to the bonding energy and can be defined as adsorption or distribution coefficient and represents the general capacity of dye adsorbed onto adsorbents for a unit equilibrium concentration (i.e., $C_e = 1 \text{ mg dm}^{-3}$). The slope $1/n$, ranging between 0 and 1, is a measure for the adsorption intensity or surface heterogeneity. A plot of $\ln q_e$ vs $\ln C_e$ enables the empirical constants K_F and $1/n$ to be determined from the intercept and slope of the linear regression. Judging the correlation coefficients, R^2 , compares applicability of the isotherm equations.

The results of Langmuir and Freundlich isotherms fitted by using the data of adsorption capacity from the regression of Eq. (2) at 25°C is presented in Table 5. Obviously, it can be seen in Fig. 3 that both the Langmuir and Freundlich models seemed to describe well the adsorption behavior of ethyl violet from aqueous solution onto RSBE, as reflected by correlation coefficients (R^2) of 0.9671 and 0.9437, respectively. The adsorption isotherm revealed that the regenerated clay adsorbent uptakes 40.7 mg g^{-1} in relatively low concentration of the basic dye in aqueous medium. As also illustrated in Table 5, the value of $1/n$ is 0.164 indicating a slight favorable adsorption system for which $0 < 1/n < 1$.

In order to obtain the preliminary information on the adsorption capacity of standard activated carbon as compared to that of RSBE, the granular activated carbon (denoted as PCB) with BET surface area of $1012 \text{ m}^2 \text{ g}^{-1}$ [28], obtained from Calgon Carbon Co. (Pittsburgh, USA), was studied to obtain its fitting adsorption capacities from the adsorption kinetic experiments at initial ethyl violet concentrations of 10 and 20 mg dm^{-3} under the conditions of dosage = $0.5 \text{ g } 2.0 \text{ dm}^{-3}$, temperature = 25°C , agitation rate = 400 rpm, and pH 7.0. It was found that the fitting adsorption capacities are 17.83 and 25.91 mg g^{-1} , respectively. By comparison with the data in Tables 1 and 2, the equilibrium adsorption capacities (i.e., 17.83 vs 35.6 mg g^{-1} and 25.91 vs 46.5 mg g^{-1}) are not in accordance with the order of pore properties, (i.e., 1012 vs $117 \text{ m}^2 \text{ g}^{-1}$), implying that the basic dye adsorbs largely and strongly on the clay mineral, somewhat less on activated carbon in that its surface is generally non-polar [13].

4. Conclusions

This study showed that spent bleaching earth from edible oil processing industry could be used as a precursor for the preparation of an effective clay adsorbent for the removal of ethyl violet from aqueous solution. The adsorption of basic dye is pH and temperature dependent. The maximum adsorption capacity of ethyl violet from aqueous solution took place at basic condition (pH 11) or acidic condition (pH 3), while the dye adsorption showed a minimum around pH 9. An increase in temperature from 15 to 45°C significantly enhances the adsorption capacity, revealing that the adsorption is endothermic in nature. The adsorption kinetics can be well described by the pseudo-second-order reaction model. Further, the both models of Langmuir and Freundlich model seemed to describe well the adsorption behavior of ethyl violet from aqueous solution onto RSBE. From the views of environmental protection and resource recycling, the clay adsorbent prepared from spent bleaching earth is an option for the removal of environmental organic pollutants from the aqueous medium.

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