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Batch Adsorption Study of Bentazon Herbicide from Aqueous Solution Using Coconut Activated Carbon

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Abstract

Adsorption study of bentazon from aqueous solution using commercial coconut activated carbon (CCAC) as adsorbent has been carried out in batch process. The experimental data were analyzed by the Langmuir isotherm, the Freundlich isotherm and the Temkin isotherm. Equilibrium data fitted well with the Langmuir model with maximum adsorption capacity of 111.1 mg/g at 30°C when the initial concentration was 25–250 mg/L. Pseudo-first and pseudo-second-order kinetics models were tested with the experimental data, and pseudo-second-order kinetics was the best for the adsorption of bentazon by CCAC with coefficients of correlation $R^2 \geq 0.988$ for all initial bentazon concentrations studied.

Introduction

Pesticides may be of the board spectrum type which kills a wide range of organisms or the selective type which destroys one organism or few specific organisms [1]. Pesticides are applied to agricultural crops and amenity land as part of the normal management of those areas for best yield or general maintenance respectively [2]. Pesticides concentrations in wastewater and aqueous solution are within the range of 20-400 mg/L [3].

Pesticides are indispensable in modern agriculture, but their use and/or misuse may lead to serious deterioration in water quality which could impair the use of water for purposes of crop protection, animal production or even human consumption.

Bentazon is a newly emerging herbicide used for selective control of broadleaf weeds and sedges in beans, rice, corn, peanuts, and mint. It is one of the most commonly used herbicides in agriculture and gardening. However, through leaching or run-off from agricultural lands, deposition from aerial applications and indiscriminate discharge of industrial wastewaters, bentazon has become a reckoned source of contaminant to water resources with its attendant threats to the ecosystem and environment in general; the maximum allowable concentration is 0.05 mg/L in tap water [4].

Several methods either independent or in conjunction have been used for the removal of these pesticides including chemical oxidation with ozone [5], photo degradation [6], combined ozone and UV irradiation [7], Fenton degradation [8], biological degradation [9], ozonation [10], membrane filtration [11] and adsorption [12].

Adsorption technology has been widely used to remove toxic compounds from polluted waters and is presently the most viable option being employed for the removal of pesticides from wastewaters. Activated carbon (AC) or other highly porous materials, such as synthetic resins, are commonly utilized as adsorbents. AC is a widely used adsorbent in the treatment of wastewater and drinking water because it possesses desirable physiochemical properties including good mechanical strength, chemical stability in diverse media, and large pore size distribution in addition to its extensive specific surface area [13].

Material and methods

Pesticide and activated carbon:

Technical grade bentazon supplied by Sigma-Aldrich was used as an adsorbate. Distilled water was used to prepare all solutions. Commercial coconut activated carbon (CCAC) used in this study.

Batch equilibrium studies:

Adsorption tests were performed in a set of Erlenmeyer flasks (250 ml) where 100 mL of bentazon solutions with initial concentrations of 25-250 mg/L were placed in these flasks. Equal amount of 0.3 g of activated carbon was added to each flask and kept in an isothermal (30°C) shaker at 120 rpm for 22 h to reach equilibrium. At intervals of time, samples were taken from the solution and the concentrations determined. All samples were filtered prior to the analysis in order to minimize the interference of carbon fines present in solution. The concentrations of bentazon in the supernatant solution before and after adsorption were determined using a double beam UV-visible spectrophotometer (Shimadzu 1700, Japan) at 333 nm. Each experiment was duplicated under identical conditions. The amount of adsorption at equilibrium, q_e (mg/g), was calculated by:

$$q_e = \frac{(C_o - C_e)V}{W} \qquad (1)$$

where C_o and C_e (mg/L) are the liquid phase concentrations of bentazon at the initial and equilibrium conditions, respectively. V (L) is the volume of the solution and W (g) is the mass of CCAC.

Adsorption Isotherm:

Three isotherm models (Langmuir, Freundlich and Timken) were used to test the fitting of the experimental data. The linear form of Langmuir isotherm equation [14] is given as:

$$\frac{C_e}{q_e} = \frac{1}{q_m b} + \frac{C_e}{q_m} \qquad (2)$$

where C_e(mg/L) is the equilibrium concentration of the adsorbate, q_e(mg/g) is the amount of adsorbate adsorbed per unit mass of adsorbent, q_m (mg/g) is a monolayer adsorption capacity, and b(L/mg) is the equilibrium adsorption constant. The linear form of Freundlich [15] isotherm is given by the following equation:

$$\log q_e = \ln K_F + \left(\frac{1}{n}\right) \log C_e \qquad (3)$$

where C_e (mg/L) is the equilibrium concentration of the adsorbate, q_e (mg/g) is the amount of adsorbate adsorbed per unit mass of adsorbent, K_F (mg/g(l/mg)$^{1/n}$) and n are Freundlich constants. In the case of, Timken isotherm [16], it is used in the form given below.

$$q_e = B\ln A + B\ln C_e \quad (4)$$

where B = RT/b and b (J/mol) is the Temkin constant related to heat of sorption; A (l/g) is the Temkin isotherm constant, R (8.314 J/mol K) the gas constant and T (K) the absolute temperature.

Results and discussion

Effect of contact time and initial bentazon concentration on adsorption equilibrium:

Figure 1 and 2 shows the bentazon concentration decreasing and adsorption uptake with time for various initial bentazon concentrations at 30°C. It indicated that the contact time needed for bentazon solutions with initial concentrations of 25 - 50 mg/L to reach equilibrium were 3-4 hr. For bentazon solutions with initial concentrations of 100-150 mg/L, equilibrium time of 10 hr was required.While 20 hr enough for bentazon solutions within the initial concentrations of 200-250 mg/L to reach the equlibrum.

As would be observed from Figure 1, the amount of bentazon adsorbed onto the surface of activated carbon increased with time.

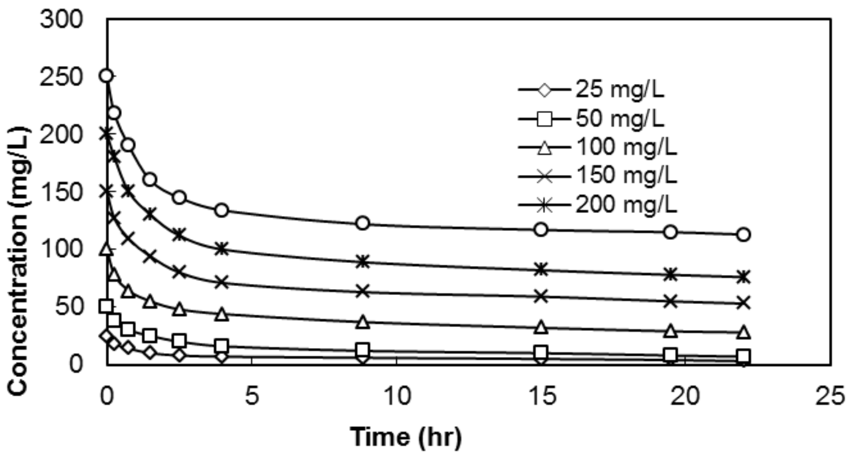

Figure 1. Concentration with contact time for various intial concentration of bentazon onto CCAC.

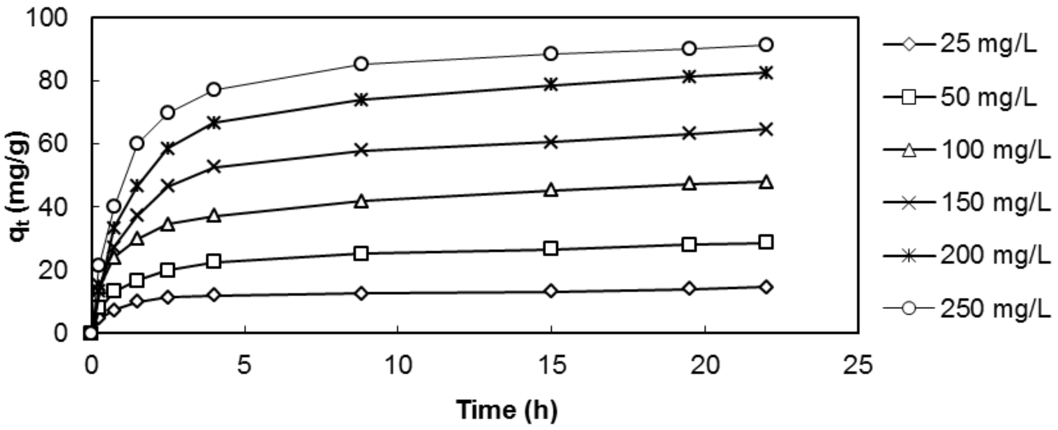

Figure 2. Adsorption capacity with contact time of various intial concentration of bentazon onto CCAC.

Adsorption isotherms:

The adsorption isotherm indicates how the adsorption molecules distribute between the liquid phase and the solid phase when the adsorption process reaches an equilibrium state. The analysis of the isotherm data by fitting them to different isotherm models is an important step to find the suitable model that can be used for design purposes [17]. Adsorption isotherm is basically important to describe how solutes interact with adsorbents, and is critical in optimizing the use of adsorbents. Adsorption isotherm study was carried out on three isotherm models: the Langmuir, Freundlich and Temkin isotherm models. The applicability of the isotherm models to the adsorption study done was compared by judging the correlation coefficients, R^2 values.

The Langmuir, Freundlich and the Temkin isotherms were used to describe the experimental results (Figures 3,4 and 5). The linear plot of specific adsorption (C_e/q_e) against the equilibrium concentration (C_e) gave the Langmuir constant, q_m and R^2, which were determined from the slope and intercept of the plot and are presented in Table 1. Similarly, the values of K_F and n for Freundlich isotherm were calculated from the intercept and slope of equation 3 are given in Table 1 and the constants A and B of Temkin isotherm described by equation 4 above are also presented in Table 1. As would be observed from Table 1, the monolayer adsorption capacity according to Langmuir is model is 111.1 mg/g for bentazon. The correlation coefficient (R^2), which describes the fitness of a set of data revealed that Langmuir isotherm best describes the adsorption of the considered pesticides than the others with R^2 of 0.968 for bentazon. The fact that the Langmuir isotherm fits the experimental data very well may be due to homogeneous distribution of active sites onto CCAC surface.

Table 1. Langmiur, Frendulich, and Temkin isotherm models

Langmuir isotherm	**Value**
q_m (mg/g)	111.11
b (L./mg)	0.0383
R^2	0.968
Freundlich isotherm	
N	2.05
K_F [(mg /g)(L./mg)$^{1/n}$]	9.50
R^2	0.984
Temkin isotherm	
A (L/g)	0.577
B (J/mol)	20.66
R^2	0.96

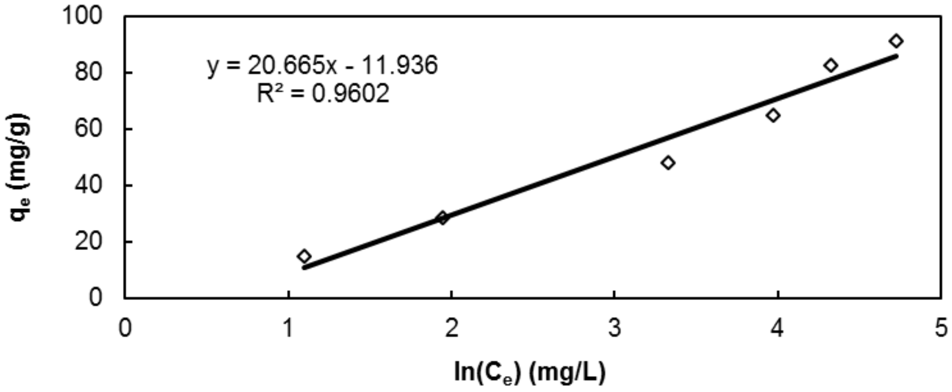

Figure 3. Langmuir adsorption isotherm of bentazon onto CCAC at 30 °C

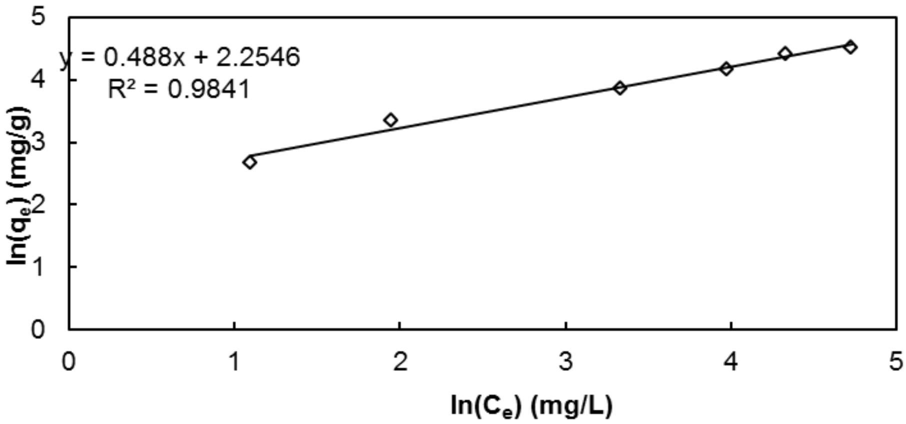

Figure 3. Temkin adsorption isotherm of bentazon onto CCAC at 30 °C

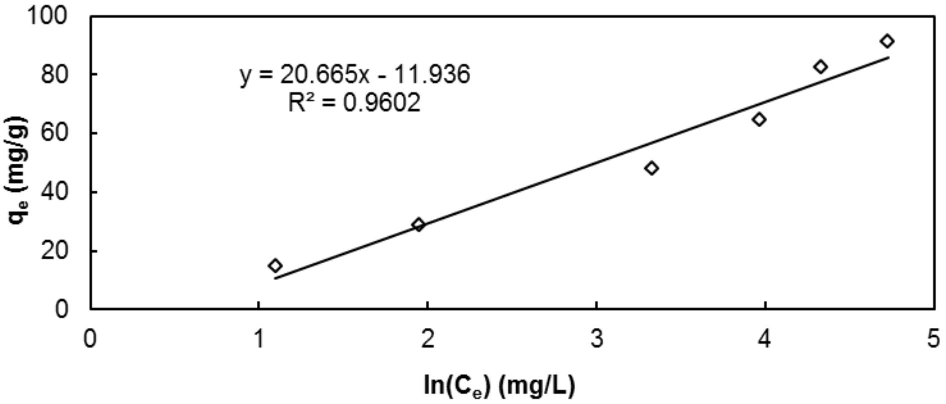

Figure 3. Temkin adsorption isotherm of bentazon onto CCAC at 30 °C

Conclusion

The present investigation showed that commercial coconut activated carbon is a promising adsorbent for the removal of bentazon from aqueous solutions. Equilibrium data were fitted to Langmuir, Freundlich and Temkin isotherms and the equilibrium data were best described by the Langmuir isotherm model; with a maximum monolayer adsorption capacity of 111.1 mg/g at 30°C for bentazon. The kinetics of the adsorption process was found to follow the pseudo-second-order kinetic model.

دراسة الأمتزاز المرحلي لمبيد الأدغال البنتازون من المحاليل المائية باستخدام كربون الكوكونت المنشط التجاري

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وزارة الصناعة والمعادن- بغداد- العراق

و

عبد علي عبد الزهرة شهد

الخلاصة

تم دراسة ازالة مبيد الأدغال البنتازون من المحاليل المائية بطريقة الأمتزاز المرحلي باستخدام كربون الكوكونت المنشط التجاري كمادة مازة. تم اختبار و تدقيق تطابق نتائج عملية الأمتزاز هذه باستخدام ثلاث موديلات قياسية وهي موديل لنكمر، موديل فريندليج و موديل تيمكن. نتائج الاتزان لعملية الأمتزاز أعطت تطابق مع موديل لنكمر وبقدرة امتصاص ١١١,١ ملغم/غم عند درجة حرارة ٣٠ °م وعلى مدى التركيز الأولي لمحاليل مبيد البنتازون ٢٥-٢٥٠ ملغم/لتر.

تم اختبار عملية الأمتزاز في بحثنا هذا باستخدام موديلين رياضيين للاتزان الحركي للمحاليل السائلة وهما الموديل الأول والثاني لحركية السوائل عند الاتزان لأغراض التصميم لموديل الأمتزاز الأفضل لعملية ازالة المبيد وقد تبين مطابقة النتائج مع الموديل الحركي الثاني حسب معطيات ونتائج التجارب وتطابق قيم الأمتزاز النظري مع قيم ونتائج الامتصاص التجريبي ووفقا لنتائج قيم معامل التصحيح والتي تجاوزت ٠,٩٨٨.

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