



BATCH STUDY FOR HERBICIDE BENTAZON ADSORPTION ONTO PALM OIL FRONDS ACTIVATED CARBON

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ABSTRACT

The adsorption of herbicide bentazon from aqueous solution onto activated carbon derived from palm oil fronds (PFAC) was investigated through batch study. The effects of both; initial concentration of the bentazon (ranging from 25 to 250 mg/L) and pH of solution (ranging from 2 to 12) on the adsorption of the prepared PFAC were studied in batch experiments. Equilibrium data were fitted to the Langmuir, the Freundlich and the Temkin isotherm models. The results obtained from application of these models show that the best fits were achieved with the Langmuir model and a maximum monolayer adsorption capacity of 104.2 mg/g was obtained at 30°C. The regeneration efficiency of spent activated carbon was studied and it was found to be 94.0-96.1%. The results indicated that PFAC has good capability as adsorbent for the removal of bentazon from aqueous solutions.

Key words: Bentazon, Adsorption, Desorption, Activated carbon, Palm oil fronds.

INTRODUCTION

Pesticides are chemicals, which are commonly used in agriculture to protect crops from pest organisms including insects, plants, fungi, rodents and nematodes. They may appear as pollutants in water sources and threat to human health because of their toxicity, carcinogenicity and mutagenicity. In developed countries, drinking water quality has strict regulations regarding pesticides¹.

Presently, on a worldwide basis, intoxications attributed to pesticides have been estimated to be as high as 3 million cases of acute and severe poisoning annually, with many unreported cases and with some 220000 deaths². This situation calls for urgent attention with acceptable solution for the removal of pesticides from water sources. This is because pesticides will continue to be used effectively for pest controls and the responsibility rest on

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us to find ways of avoiding many of the pesticides poisonings and contaminations that exist today.

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^{3,4}.

There are several methods either independent or in conjunction that have been used for the removal of pesticides from water, such as chemical oxidation with ozone⁵, photocatalytic method⁶, combined ozone and UV irradiation⁷, ozonation⁸, membrane filtration⁹ and adsorption¹⁰. Adsorption is one of the most frequently applied methods because of its efficiency, capacity and applicability on a large scale. The most commonly used adsorbent in adsorption processes is activated carbon due to its efficiency and economic feasibility. Utilization of activated carbon can be in the form of powder, granular and fiber or cloth. Recently, growing research interest in the production of carbon-based activated carbon has been focused on agricultural by-products. Low cost adsorbents derived from agricultural wastes have demonstrated outstanding capabilities for the removal of pollutants from wastewater. Therefore, low cost agricultural waste adsorbents can be viable alternatives to activated carbon for the treatment of contaminated wastewater. The use of cheap and eco-friendly adsorbents have been studied as an alternative substitution to activated carbon for the removal of dyes from wastewater¹¹.

EXPERIMENTAL

Methods

Bentazon

Bentazon supplied by Sigma–Aldrich Sdn Bhd, was used as the adsorbate in this study. Deionized water was used to prepare all the solutions.

Preparation and characterization of activated carbon

Palm oil fronds (POF) were used as a starting material for preparation of activated carbon, which was cut into pieces, dried in air until the weight was constant. The dried pieces were then crushed using a grinder and thereafter screened to particle size range of 1-4

mm. The screened POF were then carbonized in a stainless steel, vertical tubular reactor, placed in a tube furnace. The temperature of the furnace was ramped from room temperature to 700°C at heating rate of 10°C/min and held for 2 h under nitrogen (99.995%) flowing at the rate of 150 cm³/min. The char produced from the carbonization process was subsequently impregnated with KOH pellets (KOH/Char = 2.75 by weight). The impregnated char was thermally treated under nitrogen to a final temperature of 850°C. Once the final temperature was reached, the nitrogen gas flow was switched over to CO₂ and held under that condition for 1 h. The PFAC produced was then cooled to room temperature under nitrogen flow (150 cm³/min) and thereafter washed with 0.1 M HCl and hot distilled water to bring the pH of the washing filtrate to about 7.

The surface area, pore size distribution, and the pore volume of the developed PFAC were analyzed using Micromeritics (Model ASAP 2020, USA – surface area and porosity analyzer) employing nitrogen adsorption isotherm at 77 K. In order to determine the surface morphology of the PFAC, the sample was examined using Scanning Electron Microscope (SEM) – model: Leo Supra 35 VP Field Emission SEM.

Batch equilibrium studies

Effect of bentazon initial concentration and solution pH

In order to study the effect of bentazon initial concentration and contact time on the adsorption uptake, 200 mL of bentazon solutions with initial concentrations of 25, 50, 100, 150, 200 and 250 mg/L were prepared in a series of 250 mL Erlenmeyer flasks, and 0.30 g of the PFAC was added into each flask and covered with glass stopper. The flasks were then placed in an isothermal water-bath shaker at 30°C, with agitation speed of 120 rpm. At specific time intervals, samples were withdrawn for analysis, using a double beam UV-vis spectrophotometer (Shimadzu UV-1700, Japan) at 333 nm, until equilibrium point was reached. The effect of solution pH on the bentazon adsorption on PFAC was also examined by varying the initial pH of the solutions between 2 and 12 (using 0.1 M HCl and/or 0.1 M NaOH solutions).

Equilibrium data fitting

Three isotherm models were used to test fit the experimental data. These are Langmuir isotherm¹², the Freundlich isotherm¹³ and the Temkin isotherm¹⁴. The linear form of the Langmuir model is:

$$\frac{C_e}{q_e} = \frac{C_e}{q_m} + \frac{1}{K_a q_m} \quad \dots(1)$$

Where C_e is the equilibrium concentration (mg/L); q_e the amount bentazon adsorbed at equilibrium (mg/g); q_m the adsorption for complete monolayer (mg/g); K_a is the sorption equilibrium constant (L/mg).

The linear form of Freundlich isotherm is:

$$\ln q_e = \ln K_F + \frac{1}{n} \ln C_e \quad \dots(2)$$

The constants K_F and $1/n$ of the Freundlich model are the constants indicative of the relative adsorption capacity of the adsorbent and the intensity of the adsorption, respectively. The Temkin isotherm has been used in the form as follows:

$$q_e = B \ln A + B \ln C_e \quad \dots(3)$$

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

Regeneration of activated carbon

The feasibility of regenerating the spent activated carbon was evaluated using ethanol desorption technique¹⁵. Batch equilibrium tests were performed on the fresh activated carbon prepared, where 100 mL of bentazon solution with initial concentration of 200 mg/L were placed in 250 mL Erlenmeyer flasks. 0.30 g of the fresh PFAC was added into the flask and placed in an isothermal water bath shaker at 30°C, with agitation speed of 120 rpm, for 48 h until complete equilibrium was attained. The spent activated carbon was then separated from the solution and dried at 105°C in an oven. It was thereafter mixed with 100 mL of 95 vol. % ethanol in an Erlenmeyer flask for the desorption of the adsorbed bentazon. The flask was kept in the isothermal water-bath shaker at the same temperature for the same time duration as the adsorption tests. Desorption percentage was calculated from equation (4):

$$\text{Desorption \%} = \left(\frac{C_{de}}{C_{ad}} \right) \times 100 \quad \dots(4)$$

Where the C_{de} (mg/L) is the concentration of bentazon at equilibrium in desorption process, and C_{ad} (mg/L) represents the difference between the initial and equilibrium concentrations of bentazon in adsorption process.

RESULTS AND DISCUSSION

The morphological and textural characteristics of the developed PFAC

Fig. 1 shows the scanning electron microscopy (SEM) image of the produced PFAC. The PFAC depicts a surface containing a well-developed pores expected of a good adsorbent, in which the carbonaceous matters and salts that could have blocked the pores as seen in the precursor had been leached off by the activation process, showing the efficacy of the thermochemical activation method adopted in this investigation. This observation is well corroborated by the Brunauer-Emmett-Teller (BET) surface analysis ($1237.13 \text{ m}^2/\text{g}$, $0.66723 \text{ cm}^3/\text{g}$ and 2.157 nm , values for surface area, pore volume and pore diameter, respectively).

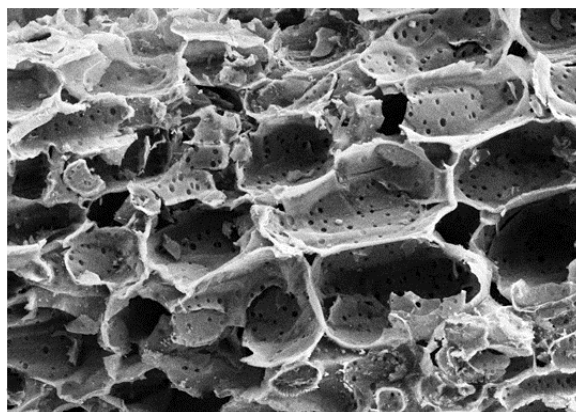


Fig. 1: Surface morphology of the PFAC (magnifications: 500 X)

Effect of initial concentration and agitation time on bentazon adsorption

The effect of bentazon initial concentration and agitation time on the bentazon adsorption onto the PFAC is shown in Fig. 2. It is clear that the amount of bentazon adsorbed, q_t , increased onto PFAC surface. The adsorption uptake at equilibrium was found to increase with an increase in the initial insecticide concentration as appeared in Fig. 2, which shows that longer contact times were required to reach equilibrium by the bentazon solutions of higher initial concentrations.

Fig. 2 shows that longer contact times are required by the bentazon solutions of higher initial concentrations to reach equilibrium. The contact times needed for bentazon solutions with initial concentrations of 25-150 mg/L to reach equilibrium onto PFAC was around 4 h. However, for higher initial concentrations (200-250 mg/L) of bentazon solutions, it will require 10 h equilibrium.

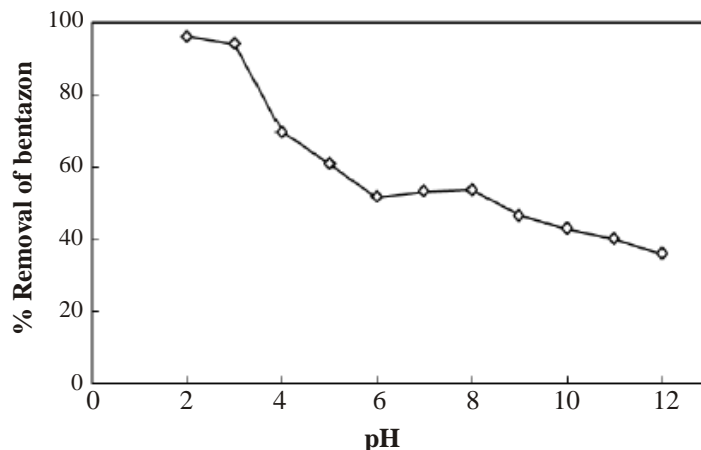


Fig. 2: Effect of bentazon initial concentration and agitation time on carbofuran adsorption capacity

Adsorption of bentazon was fast due to the high affinity of the interacting groups on the surface of the activated carbon. The high adsorption rate at the beginning of adsorption was due to the adsorption of bentazon to the exterior surface of the adsorbent. The high adsorption uptake of activated carbons prepared in this work were due to the presence of functional groups such as hydroxyl, carbonyl which dissociate and hence, the electrostatic attraction between the activated carbon surface and insecticide. Similar trend has been reported for bentazon adsorption onto carbon slurry¹⁶. The rate of uptake is rapid in the beginning and the rate of adsorption was found to depend on the initial concentration of pesticide.

Effect of solution pH on bentazon adsorption

The effect of pH on bentazon adsorption was studied by varying the pH from 2 to 12 using 200 mL of a 100 mg/L fixed initial concentration of bentazon at 30°C. The equilibrium adsorption (q_e) of bentazon on the activated carbon used was found to decrease and, as a result, the percent removal (%) decreases, when the initial pH of the aqueous solution was increased from 2 to 12 (Fig. 3).

The observed change in solution pH could have had effect on the properties of pesticide molecules and consequently on their adsorptions. Additionally, the surface functional groups of the adsorbent make the adsorption process complicated. It is also possible that the surface properties of the activated carbon have been altered as a result of the pH of the solution. Thus, the surface charge would depend on the solution pH and the surface characteristics of the carbon¹⁷.

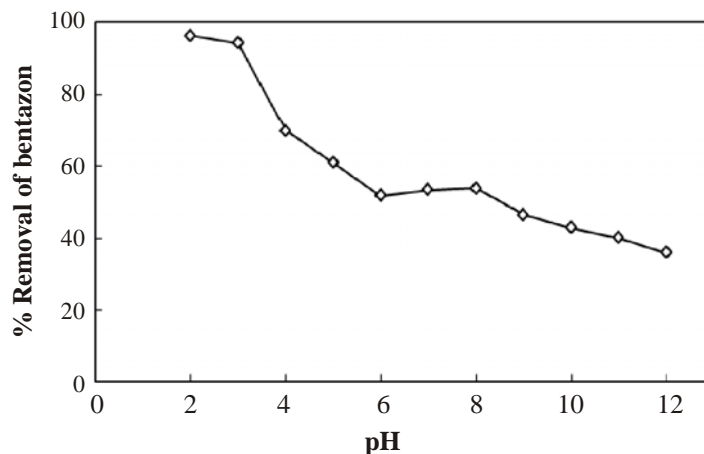


Fig. 3: Percent removal (%) of bentazon on PFAC as a function of pH

Due to the presence of secondary and tertiary amine, behaving as bases (accepting protons), bentazon is expected to be positively charged at low pH and neutral at high pH (illustrated in Fig. 4). Based on the result in Fig. 3, the exterior surface of PFAC is likely to be negatively charged. Higher adsorption at lower pH could be attributed to the electrostatic attraction between the positively charged bentazon (after accepting a proton) and negative surface of the PAFC.



Fig. 4: Structural formula of bentazon at low pH (left), and at high pH (right), as theoretically expected to be positively charged at low pH due to the presence of secondary and tertiary amine.

Adsorption isotherm

The equilibrium data for bentazon adsorption on PFAC were modeled with three linearized expressions of the Langmuir, the Freundlich and the Temkin isotherm models (Figures not shown). Table 1 summarizes all the constants and correlation coefficients, R_2 of these three isotherm models at 30°C. The Langmuir model yielded the best fit with R_2 , which were higher than 0.962. The monolayer adsorption capacity according to Langmuir model was 104.2 mg/g.

Table 1: Langmuir, Freundlich and Temkin isotherm model parameters and correlation coefficients for adsorption of bentazon on PFAC at 30°C

Isotherm models		Parameters	
Langmuir	q_m (mg/g)	b (L/mg)	R^2
	104.2	0.054	0.962
Freundlich	K_F (mg/g (L/mg) ^{1/n})	$1/n$	R^2
	12.81	0.427	0.941
Temkin	A (L/g)	B	R^2
	1.17	19.11	0.943

Regeneration of activated carbon

The activated carbon derived from palm oil fronds (PFAC) that adsorbed bentazon was regenerated by ethanol. The desorption of bentazon from spent PFAC was repeated for four cycles for adsorption and four cycles for desorption using the same activated carbon for the starting cycle. The regeneration efficiency was found to be 94-96.1%. This result indicates that the prepared activated carbon has a good regeneration and reusability characteristics for the adsorption of bentazon and can be used as an alternative to the presently available commercial activated carbons.

CONCLUSION

This work examined the feasibility of activated carbon prepared from palm oil fronds (PFAC) for the adsorption of bentazon herbicide from aqueous solutions over a wide range of concentrations. It was found that the PFAC was very effective for this purpose. Equilibrium data were fitted to the Langmuir, Freundlich and Temkin isotherms and the equilibrium data were best described by the Langmuir isotherm model, with the maximum monolayer adsorption capacity of 104.2 mg/g. In the pH tested (ranging from 2-12), higher adsorption of bentazon on the PFAC was observed at lower pH. Ethanol desorption technique was efficient in regenerating the spent activated carbon and this provides a good ground for the reusability of the PFAC in subsequent adsorption runs.

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