



# REMOVAL OF PHENOLIC COMPOUNDS FROM AQUEOUS SOLUTIONS BY ADSORPTION ONTO ACTIVATED CARBONS PREPARED FROM DATE STONES BY CHEMICAL ACTIVATION WITH $FeCl_3$

Samar K. Dhidan

Chemical Engineering Department-College of Engineering-University of Baghdad-Iraq

E-mail: [samarkarim26@yahoo.com](mailto:samarkarim26@yahoo.com)

## Abstract

Activated carbon prepared from date stones by chemical activation with ferric chloride (FAC) was used as an adsorbent to remove phenolic compounds such as phenol (Ph) and p-nitrophenol (PNPh) from aqueous solutions. The influence of process variables represented by solution pH value (2-12), adsorbent to adsorbate weight ratio (0.2-1.8), and contact time (30-150 min) on removal percentage and adsorbed amount of Ph and PNPh onto FAC was studied. For PNPh adsorption, (97.43 %) maximum removal percentage and (48.71 mg/g) adsorbed amount was achieved at (5) solution pH, (1) adsorbent to adsorbate weight ratio, and (90 min) contact time. While for Ph adsorption, at (4) solution pH, (1.4) adsorbent to adsorbate weight ratio, and (120 min) contact time gave maximum removal percentage (86.55 %) and (43.27 mg/g) adsorbed amount. Equilibrium adsorption data of PNPh and Ph onto FAC were well represented by Langmuir isotherm model, showing maximum adsorbed amounts of (185.84 mg/g) and (159.27 mg/g) for PNPh and Ph, respectively.

## الخلاصة

يهدف البحث إلى إزالة المركبات الفينولية مثل الفينول والبارانايتروفينول من المحاليل المائية باستخدام الكربون المنشط والمحضر من نوى التمر بطريقة التنشيط الكيميائي مع كلوريد الحديد كمادة مازة. تم دراسة تأثير قيمه pH (2-12)، نسبة المادة المازة إلى المادة الممتزة (0.2-1.8)، وزمن امتزاز (30-150 دقيقة) على النسبة المئوية للإزالة والكمية الممتزة لكل من الفينول والبارانايتروفينول. تم الحصول على نسبة إزالة بارانايتروفينول (97.43 %) وسعة امتزاز (48.71 ملغم/غرام) عند الظروف التشغيلية: pH (5)، نسبة مادة مازة إلى ممتزة (1)، وزمن امتزاز (90 دقيقة). في حين لامتزاز مادة الفينول، تم الحصول على نسبة إزالة (86.55 %) وسعة امتزاز (43.27 ملغم/غرام) عند الظروف التشغيلية: pH (4)، نسبة مادة مازة إلى ممتزة (1.4)، وزمن امتزاز (120 دقيقة). تم استخدام معادله لانكماير بشكل ناجح لتمثيل نتائج امتزاز كل من الفينول والبارانايتروفينول على الكربون المحضر، حيث أعطى أعلى سعة امتزاز للفينول (159.27 ملغم/غرام) وأعلى سعة امتزاز للبارانايتروفينول (185.84 ملغم/غرام).

**KEYWORDS:** Activated carbon, chemical activation, ferric chloride, date stones, phenolic compounds

## 1. INTRODUCTION

Phenolic compounds are classified to be extremely toxic for human beings and for all aquatic life. One of the most hazardous polluting phenolic compounds to the environment is phenol, which can exert negative effects on different biological processes and their present even at low concentrations can cause unpleasant taste and odor of drinking water and can be an obstacle to the use of waste water (Dabrowski et al., 2005). The other important polluting phenolic is p-nitro phenol, which is known to be persistent, bioaccumulative, and high toxic. It can enter the human body through all routes and its toxic action is much like that of aniline. P-nitro phenol aids the conversion of hemoglobin to methemoglobin, which is caused by the oxidation of iron (II) to iron (III) with the result that the hemoglobin can no longer transport oxygen in the body. Therefore, the complete removal of p-nitro phenol or in some cases reduction of its concentration in wastewaters to an acceptable level has become a major challenge (Al-Asheh et al., 2004). Industrial sources of environmental contaminants such as oil refineries, coal gasification sites, and petrochemical and pharmaceutical industries generate large amounts of these polluting materials (Canizares et al., 2006).

Several ways have been developed to remove phenolic compounds from wastewaters, including electrochemical oxidation (Juttner et al., 2000), chemical coagulation (Tomaszewska et al., 2004), solvent extraction (Lazarova and Boyadzhieva, 2004), membrane separation (Kujawski et al., 2004), and photocatalytic degradation (Sona et al., 2007). Yet, still the adsorption technique using activated carbon is the most favorable method. The relative advantages of adsorption over other conventional advanced treatments methods are: it can remove both organic as well inorganic constituents even at very low concentration, it is relatively easy and safe

to operate, both batch and continuous equipment can be used, no sludge formation, and the adsorbent can be regenerated and reused again. Moreover the process is economical because it requires low capital cost and there are abundant low cost materials available which can be used as adsorbents (Halouli and Drawish., 1995).

Activated carbon is the most popularly used adsorbent for phenol and its derivatives. Despite its frequent use, activated carbon remains an expensive material. Petroleum residues, natural coal and woods were for a long time, the main activated carbon precursor (Guo and Lua, 2003). But, since a few years, other precursors at low cost and easily available were used. Biomass mainly derived from agricultural solid waste is a preferable option for activated carbon precursors. Biomass materials are cheaper, renewable and abundantly available; also these materials constitute an environmental problem. As in most of the tropical countries, agricultural by products are very abundant in the Caribbean. The reuse of these solid wastes can be important for the regional economy, because high value products are obtained from low cost materials, and simultaneously bring solutions to the problem of wastes (Aduata et al., 2007).

Palm trees are abundant in several countries in the world such as Iraq, Saudi Arabia, Iran, Egypt, and other Mediterranean countries. The world annual production of dates was more than 5 million tons in 2004. Date stones as a waste stream have been a problem to the date industry. Therefore, its recycling or reutilization is useful (Haimour and Emeish, 2006). The use of date stones as a raw material produces activated carbon of high yield with good adsorption capacity for phenolic compounds adsorption (Alhamed, 2008).

Basically, activated carbon can be produced by either physical or chemical activation. Physical activation involves carbonization or pyrolysis of the



carbonaceous materials at elevated temperatures (500-900 °C) in an inert atmosphere in order to eliminate the maximum of oxygen and hydrogen dioxide (Bouchelta et al., 2008). By chemical activation it is possible to prepare activated carbon in only one step. Pyrolysis and activation are carried out simultaneously in the presence of dehydrating agents such as  $ZnCl_2$ ,  $H_3PO_4$ , and  $KCl$  (Li et al., 2010).

The use of activated carbon prepared by chemical activation with ferric chloride for removal of phenolic compounds is not completely new. (Olivera et al., 2009) used activated carbons prepared from coffee husks by chemical activation with ferric chloride for removal of phenol from aqueous solutions. However, there are no descriptions of the removal of phenolic compounds from aqueous solutions using activated carbon prepared from date stones by chemical activation with ferric chloride.

The aim of the present work is to study the removal of phenol and p-nitro phenol from aqueous solutions by adsorption onto activated carbon prepared from date stones by ferric chloride activation. The effect of contact time, pH of solution, and adsorbent to adsorbate weight ratio on the removal percentage and uptake of these compounds are also studied.

## 2. EXPERIMENTAL WORK

### 2.1 Materials

**2.1.1 Precursor:** Date stones were used as the precursor in the preparation of activated carbon. The stones as received were first washed with water to get rid of impurities, dried at 110 °C for 24 h, crushed using disk mill, and sieved.

Only the fraction of particle sizes comprised between 1 and 3 mm was selected for the preparation.

**2.1.2 Activators:** Ferric chloride (purchased from Didactic company) of purities 99.9%

were used as chemical reagents for activation of date stones.

**2.1.3 Adsorbate:** Phenol (Ph) and p-nitro phenol (PNPh) (supplied by BDH chemicals Ltd company) of purities higher than 99 % were used as adsorbate in this study.

**2.1.4 Chemicals:** All other chemical used such as hydrochloric acid, sodium thiosulfate, iodine and sodium hydroxide were of analytical grades.

**2.1.5 Adsorbents:** Commercial activated carbon (CAC1) (supplied by Didactic company) of purity 99.9% made in Espan with surface area 1080.11 ( $m^2/g$ ) and bulk density 0.454 ( $g/ml$ ), Charcoal activated granular (CAC2) (supplied by Carlo Erba Reagenti company), with surface area 555( $m^2/g$ ) and bulk density 0.529 ( $g/ml$ ).

### 2.2 Activated carbon preparation

10 g of dried stones was well mixed with 100 ml of  $FeCl_3$  solution at an impregnation ratio of 2, (activator to date stones weight ratio), for 24 h at room temperature. The impregnated samples were next dried at 110 °C and stored in a desiccator. For the carbonization of dried impregnated samples a stainless steel reactor (2.5 cm diameter x 10 cm length) was used. The reactor was sealed at one end and the other end had a removable cover with 2 mm hole at the center to allow for the escape of the pyrolysis gases. The reactor was placed in a furnace and heated at constant rate of 10 °C /min and held at an activation temperature of 700 °C for an activation time of 1 h. At the end of activation time the carbonized samples were withdrawn from the furnace and allowed to cool. Then the samples were soaked with 0.1 M HCl solution such that the liquid to solid ratio is 10 ml/g. The mixtures were left overnight at room temperature, and then filtered and subsequently the samples were repeatedly washed with distilled water until the pH of filtrate reach 6.8 (Tan et al., 2007). After that, the samples were dried at 110 °C for 24

h. Finally the samples were stored in tightly closed bottles.

### 2.3 Characteristics of prepared activated carbon

The prepared activated carbon was characterized by selected physical properties including bulk density and surface area, chemical properties including ash content, pH and conductivity, and adsorption properties including iodine number.

#### 2.3.1 Bulk density

Bulk or apparent density is a measure of the weight of material that can be contained in a given volume under specified conditions. The volume used in this determination includes, in addition to the volume of the skeletal solids, the volume of voids among the particles and the volume of the pores within the particles. A 10 ml cylinder was filled to a specified volume with activated carbon that had been dried in an oven at 80 °C for 24 h (Ahmedna et al., 1997). The bulk density was then calculated as follows:

$$\text{bulk density} = \frac{W_C}{V_C} \quad (1)$$

Where  $W_C$  is the weight of dried activated carbon (g) and  $V_C$  is cylinder volume packed with dried activated carbon (ml).

#### 2.3.2 Ash content

The ash content of an activated carbon is the residue that remains when the carbonaceous portion is burned off. The ash content of activated carbon was determined by standard methods (ASTM Designation D-2866-94, 2000). 0.5 g of activated carbon of particle size 0.250 mm was dried at 80 °C for 24 h and placed into weighted ceramic crucibles. The samples were heated in an

electrical furnace at 650 °C for 3 h. Then the crucibles were cooled to ambient temperature and weighed. The percent of ash was calculated as follows:

$$\text{ash (\%)} = \frac{W_{S3} - W_{S2}}{W_{S1}} \times 100 \quad (2)$$

Where  $W_{S3}$  is the weight of crucible containing ash (g),  $W_{S2}$  is the weight of crucible (g), and  $W_{S1}$  is the weight of original activated carbon used (g).

#### 2.3.3 Moisture content

The moisture content of prepared activated carbon was determined using oven drying method (Adekola and Adegoke, 2005). 0.5 g of activated carbon of particle size 250  $\mu\text{m}$  was placed into weighed ceramic crucible. The samples were dried at 110 °C to constant weight. Then the samples were cooled to ambient temperature and weighed. The moisture content was calculated by the following equation:

$$\text{moisture (\%)} = \frac{W_{m3} - W_{m2}}{W_{m1}} \times 100 \quad (3)$$

Where  $W_{m3}$  is the weight of crucible containing original sample (g),  $W_{m2}$  is the weight of crucible containing dried sample (g), and  $W_{m1}$  is the weight of original sample used (g).

#### 2.3.4 pH measurement

The pH value of prepared activated carbon was determined by immersing 1 g sample in 100 ml deionized water and stirring at 150 rpm for 1 h and the pH of slurry taken (Egwaikhide et al., 2007).

#### 2.3.5 Conductivity measurement

Electrical conductivity was measured by using the method of (Ahmedna et al. 1997). A 1 wt% solution of sample in deionized water was stirred at 150 rpm at room



temperature for 20 min. Electrical conductivity was measured using an EDT instrument BA 380 conductivity meter with values micro siemens per meter ( $\mu\text{s/m}$ ).

### 2.3.6 Iodine number

Iodine number is defined as the milligrams of iodine adsorbed by one gram of activated carbon. Basically, iodine number is a measure of the micropore content of activated carbon (0 to 20 Å) by adsorption of iodine from solution. Iodine number of the prepared carbon was determined as follows: 10 ml of 0.1 N iodine solution in a conical flask is titrated with 0.1 N sodium thiosulfate solution in the presence of 2 drops of 1 wt% starch solution as an indicator, till it becomes colourless. The burette reading is corresponding to  $V_b$ . Then weigh very accurately 0.05 g of activated carbon and add it to conical flask containing 15 ml of 0.1 N iodine solution, shake the flask for 4 min and filter it, then titrate 10 ml of filtrate with standard sodium thiosulfate solution using 2 drops of starch solution as indicator, now the burette reading is corresponding to  $V_s$ . The iodine number was then calculated by using the following equation (Lubrizol, 2007):

$$IN = \frac{(V_b - V_s) \cdot N \cdot (126.9) \cdot (15/10)}{M} \quad (4)$$

Where IN is iodine number (mg/g),  $V_b$  and  $V_s$  are volumes of sodium thiosulfate solution required for blank and sample titrations (ml), respectively, N is the normality of sodium thiosulfate solution (mole/l), 126.9 is atomic weight of iodine, and M is the mass of activated carbon used (g).

### 2.3.7. Surface area

The surface areas of the prepared activated carbon was estimated through a calibration curve which has a correlation coefficient of 0.997 between the iodine numbers and BET surface area of some established activated carbons from the literature (Fadhil et al., 2008) as shown in Fig. 1.

### 2.4. Adsorption experiments

The ability of the prepared activated carbons by ferric chloride activation (FAC) to remove Ph and PNPh from aqueous solutions was determined under batch mode conditions. 50 ml samples of Ph or PNPh solutions with initial concentrations of 50 mg/l were mixed with FAC of 250  $\mu\text{m}$  particle size at 0.5-2.5 adsorbent to adsorbate weight ratio. The mixtures were added to 100 ml Erlenmeyer flasks, and the flasks were shaken in a shaker (type B. Baun Karlkolb) at 120 rpm at room temperature for 30-150 min., aqueous solutions of different pH 2-12 were used. The value of pH was varied by using 0.1 M NaOH solution or 0.1 M HCl solution. Then the samples were filtered and the residual concentrations of Ph or PNPh in the filtrate were analyzed by a UV-Visible Spectrophotometer (Shimadzu UV-160A) at maximum wave lengths of 269 and 400 nm for Ph and PNPh, respectively. The adsorbed amount at equilibrium,  $q_e$  (mg/g), and removal percentage of Ph and PNPh onto FAC were calculated according to the following expressions:

$$q_e = \frac{(C_o - C_e) V}{W} \quad (5)$$

$$RP (\%) = \frac{C_o - C_e}{C_o} \times 100 \quad (6)$$

Where RP removal percentage (%),  $C_o$  and  $C_e$  are the initial and equilibrium concentrations of Ph or PNPh solution (mg/l), respectively, V is the volume of

solution (l), and W is the weight of activated carbon used (g).

### 2.5. Adsorption isotherm of Ph and PNPh on FAC at optimum conditions

The maximum adsorption capacity of the prepared activated carbon for Ph and PNPh were determined by performing adsorption tests in a set of 100 ml Erlenmeyer flasks where 50 ml of Ph or PNPh solutions with initial concentrations of 50-250 mg/l were placed in these flasks. Then the flasks were shaken in a shaker (type B. Baun Karlkolb) at 120 rpm at room temperature. Other operating parameters such as activated carbon dosage, solution pH, and contact time were constant at their optimum values for each of Ph and PNPh adsorption onto FAC. The concentrations of Ph or PNPh solutions were similarly measured and the amount of adsorption at equilibrium,  $q_e$  (mg/g) was calculated using Eq. (5). To determine the maximum Ph or PNPh adsorption capacity of prepared activated carbon, the experimental adsorption data obtained were fitted to the Langmuir isotherm model, which can be written as follows:

$$q_e = \frac{q_m BC_e}{1 + BC_e} \quad (7)$$

Where  $q_e$  is the amount of Ph or PNPh adsorbed per unit mass of activated carbon (mg/g),  $q_m$  is the maximum amount of Ph or PNPh adsorbed per unit mass of activated carbon (mg/g),  $C_e$  is the equilibrium concentration of the Ph or PNPh (mg/l), and B is the Langmuir constant (l/mg). The Langmuir isotherm model which based on the assumption of a homogeneous adsorbent surface with identical adsorption sites has been successfully used by many researchers to correlate the experimental adsorption data of phenolic compounds on activated carbons

(Liu et al., 2010; Mohd Din et al., 2009).

## 3. RESULTS AND DISCUSSION

### 3.1 Characterization of activated carbon prepared

The property of FAC prepared was determined and compared with those determines of two types of commercial activated carbons are summarized in Table 1. The results of this table show that the surface area of FAC is 780.06 m<sup>2</sup>/g. This result is in agreement with that obtained by Rufford et al. (2010). Who showed that the surface area of activated carbon prepared by chemical activation of coffee grounds with ferric chloride was 846 m<sup>2</sup>/g. The iodine number FAC in this study are higher than that obtained by Haimour and Emeish (2006), who reported an iodine number of 495 mg/g for activated carbon prepared by chemical activation of date stones using phosphoric acid.

### 3.2. Effect of solution pH

The effect of pH on the adsorbed amount and removal percentage of phenolic compounds onto FAC is shown in Figs. 2 and 3, respectively.

It is clear from Fig.2 that the adsorbed amount increases with pH up to 4 for Ph and 5 for PNPh, thereafter it decreases. For PNPh adsorption, an increase in pH from 2 to 5 leads to an increase in adsorbed amount from 42.5 to 48.71 mg/g. While for Ph adsorption an increase in pH from 2 to 4 causes an increase in adsorbed amount from 28.4 to 35.04. The decrease in adsorbed amount of Ph or PNPh at high pH values may be due to the increase in magnitude of negative charges on Ph, PNPh, and FAC, which generate repulsion between adsorbate and adsorbent so that the amounts of Ph and PNPh adsorbed begin to decrease as mentioned by Goud et al. (2005) and Tang et al. (2007).



Fig.3 shows that 70.08 % maximum removal percentage of Ph is achieved at pH value of 4. While for PNPh, a maximum removal percentage of 97.43 % is obtained at pH of 5. Therefore, the values of 4 and 5 are considered to be the optimum pH for removal of Ph and PNPh, respectively. Similar results were reported by Mohanty et al. (2006) and Ofomaja (2011). They found that the optimum pH values were 3.5 and 4 for removal of Ph and PNPh from aqueous solutions, respectively.

### 3.3. Effect of adsorbent to adsorbate ratio

Figs. 4 and 5 show the effect of adsorbent to adsorbate weight ratio on adsorbed amount and removal percentage of Ph and PNPh, respectively.

Fig. 4 shows that the adsorbed amount of Ph and PNPh on FAC decreases as the adsorbent to adsorbate weight ratio increases. An increase in weight ratio from 0.2 to 1.8 leads to a decrease in adsorbed amount from 134.45 to 23.05 mg/g and from 217.9 to 27.1 mg/g for Ph and PNPh adsorption onto FAC, respectively. This decrease in adsorbed amount with increase in weight ratio of adsorbent to adsorbate may be due to the split in the flux or the concentration gradient between adsorbate concentration in the solution and the adsorbate concentration in the surface of the adsorbent as mentioned by Kumar et al. (2011).

Fig. 5 shows that the removal percentage of Ph and PNPh increases with increasing adsorbent to adsorbate weight ratio up to a certain value and then there is no further increase in removal percentage for both Ph and PNPh. For Ph adsorption onto FAC, an increase in weight ratio from 0.2 to 1.4 leads to an increase in removal percentage from 53.78 to 81.83 %. While for PNPh an increase in weight ratio from 0.2 to 1 causes an increase in removal percentage from 87.17 to 97.43. Therefore, the values of 1.4 and 1 can be considered as the best weight ratios which give maximum removal percentage of Ph and PNPh, respectively.

The increase in removal percentage with increasing adsorbent to adsorbate weight ratio is explained by the greater adsorbent surface area and pore volume available at higher adsorbent dosage providing more functional groups and active adsorption sites that result in a higher removable percentage as mentioned by Li et al. (2010).

### 3.4. Effect of contact time

The effect of contact time on adsorbed amount and removal percentage of Ph and PNPh is shown in Figs. 6 and 7, respectively.

The adsorbed amount of Ph and PNPh onto FAC increases with the increase of contact time, as shown in Fig. 6, and the adsorption reached equilibrium in about 90 and 120 min for PNPh and Ph, respectively. For PNPh adsorption, a rapid increase in adsorbed amount from 35.27 to 48.71 mg/g is achieved during the first 90 min. The fast adsorption at the initial stage may be due to the higher driving force making fast transfer of PNPh ions to the surface of FAC particles and the availability of the uncovered surface area and the remaining active sites on the adsorbent as mentioned by Aroua et al. (2008). While for Ph adsorption an increase in adsorbed amount from 33.42 to 43.27 mg/g is obtained with increasing contact time from 30 to 120 min.

Fig. 7 shows that the equilibrium is attained at a contact time of 90 and 120 min, giving a maximum removal percentage of 97.43 and 86.55 % for PNPh and Ph, respectively.

### 3.5. Adsorption isotherms of Ph and PNPh on prepared activated carbon

As concluded from sections 3.2, 3.3 and 3.4, the operating conditions which give maximum Ph removal percentage were chosen as 5 solution pH, 1.4 adsorbent to

adsorbate weight ratio, and 120 min contact time. While for PNPh, the operating conditions were selected as 4 solution pH, 1 adsorbent to adsorbate weight ratio, and 90 min contact time.

The experimental equilibrium data for Ph and PNPh adsorption at optimum conditions on FAC are compared with those for adsorption on two types of commercial activated carbons (CAC1) and (CAC2). These data, calculated by Eq. (5), are fitted with Langmuir isotherm model, Eq. (7), and presented in Fig. 8. The calculated constants of Langmuir isotherm equation for Ph and PNPh on the three samples along with the correlations coefficients values  $R^2$  are presented in Table 2. This table shows that the maximum Ph uptake of FAC, CAC1, and CAC2 are 159.27, 167.97, 152.68 mg/g, respectively. While for PNPh adsorption, the maximum uptake of FAC, CAC1, and CAC2 are 185.84, 193.77, and 165.45, respectively. It is clear that the adsorption capacities of the probe molecules on each activated carbon is different suggesting that the adsorption processes are associated with different chemical affinities towards the adsorbent surface area (Oliveira et al, 2009).

This result for Ph adsorption onto FAC is higher than that reported by Oliveira et al (2009), 60 mg/g, for activated carbon prepared from coffee husks by chemical activation with ferric chloride. Also, these results are higher than that obtained by Aber et al. (2009) for adsorption of Ph and PNPh onto activated carbon prepared from kenaf natural fibers using  $\text{K}_2\text{HPO}_4$  as chemical activator, they showed that the maximum adsorbed amount of Ph and PNPh were 140.84 and 136.99 mg/g, respectively.

#### 4. CONCLUSIONS

1. A maximum PNPh removal percentage of 97.43 % and 48.71 mg/g adsorbed amount were obtained at 5 solution pH, 1 FAC to PNPh weight ratio, and 90 min contact time.

2. Solution pH of 4, FAC to Ph weight ratio of 1.4, and 120 min contact time gave maximum Ph removal percentage of 86.55 % and 43.27 mg/g adsorbed amount.

3. Equilibrium adsorption data of PNPh and Ph onto FAC were well represented by Langmuir isotherm model, showing maximum adsorbed amounts of 185.84 and 159.27 mg/g for PNPh and Ph, respectively.

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## NOMENCLATURE

### Notation

B	: Langmuir adsorption constant (l/mg)
$C_o$	: Initial concentration of Ph or PNPh (mg/l)
$C_e$	: Equilibrium concentration of Ph or PNPh (mg/l)
$q_m$	: Maximum amount of Ph or PNPh adsorbed per unit mass of activated carbon (mg/g)
R	: adsorbate to adsorbent weight ratio (g/g)
$R^2$	: Correlation coefficient

t	: contact time (min)
V	: Volume of aqueous Ph or PNPh solution (l)
W	: Weight of activated carbon used (g)

### Abbreviations

CAC	: Commercial activated carbon
FAC	: Activated carbon by ferric chloride activation
Ph	: Phenol
PNPh	: P-nitro phenol

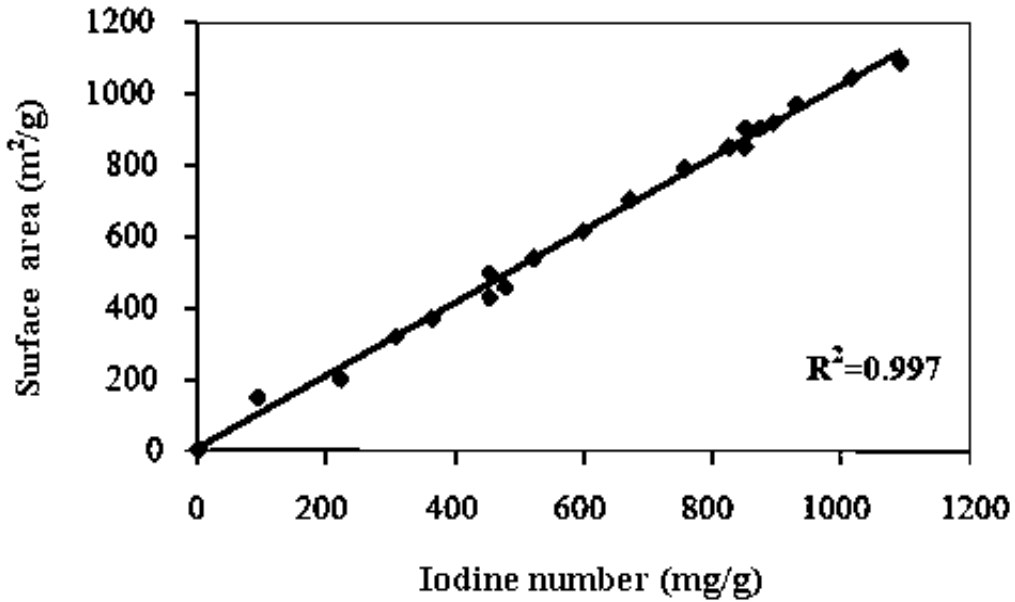


Fig. 1, Estimated surface area calibration curve

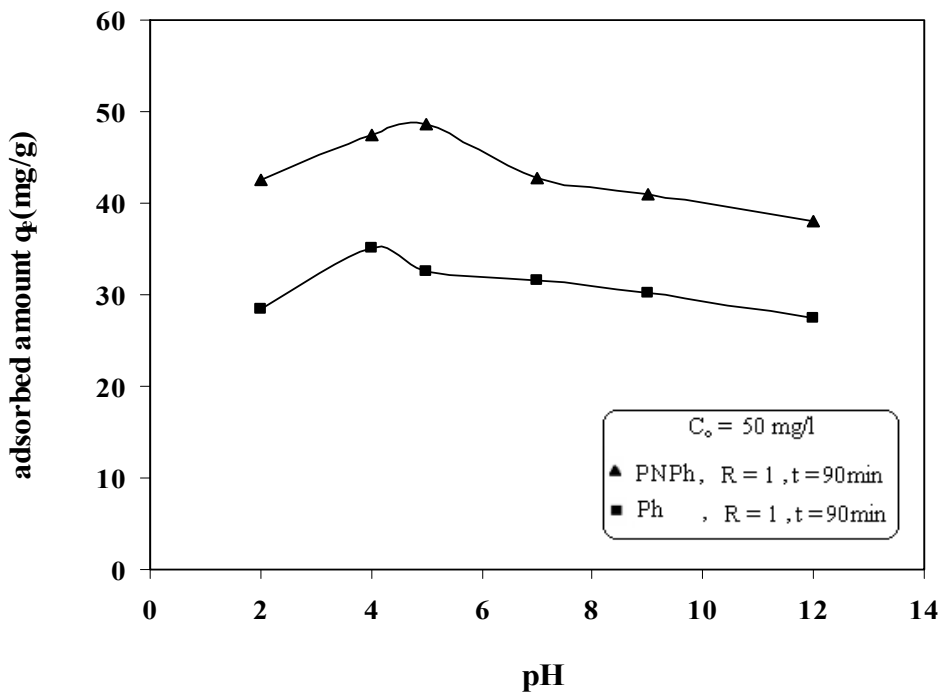


Fig. 2, Effect of solution pH on adsorbed amount

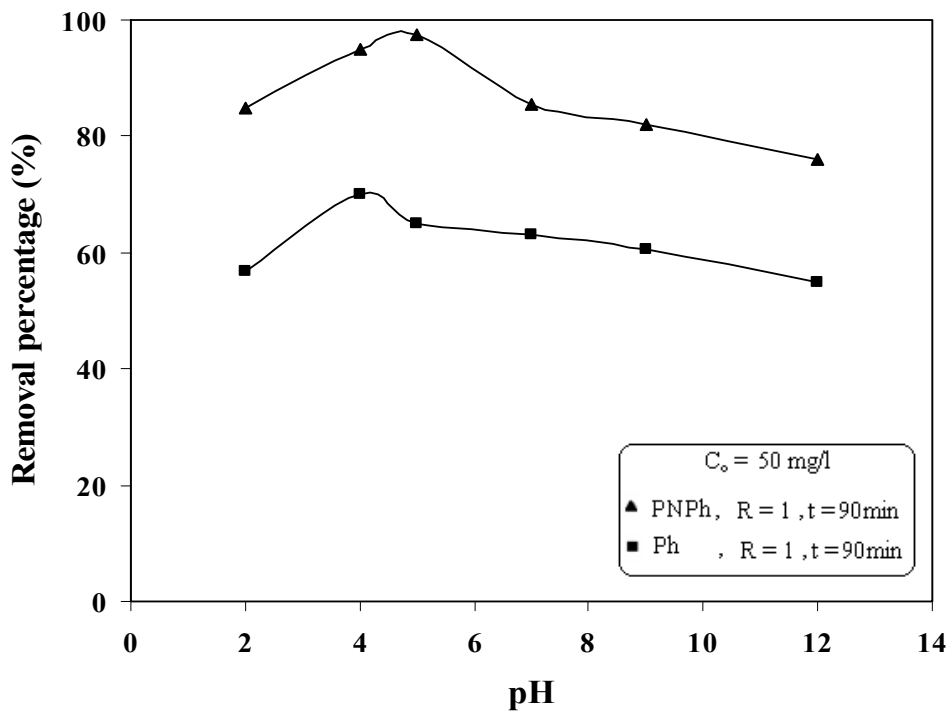


Fig. 3, Effect of solution pH on removal percentage

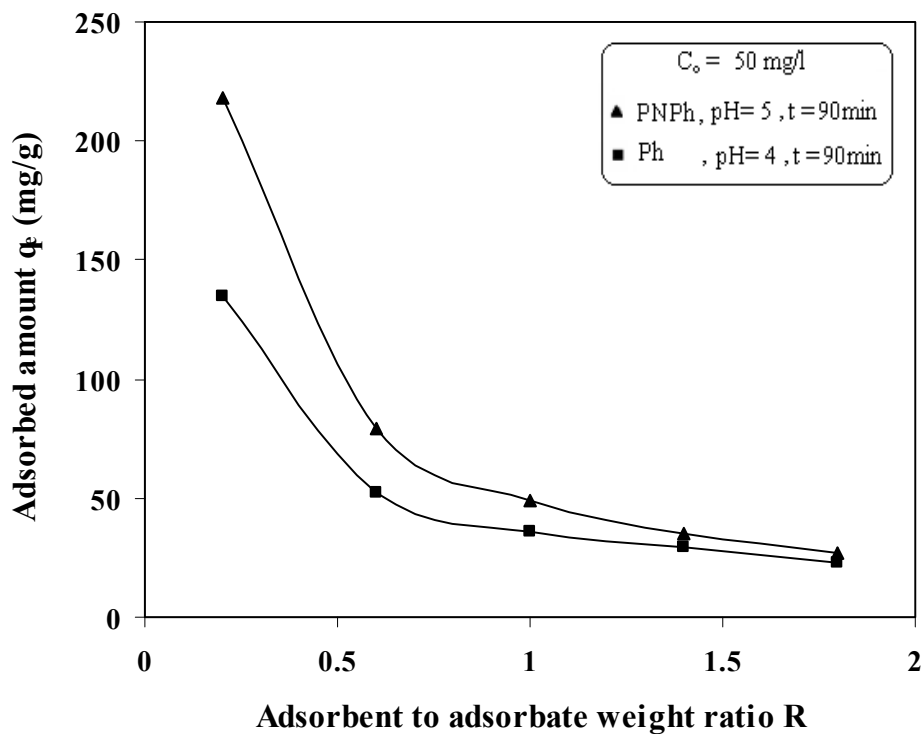


Fig. 4, Effect of adsorbent to adsorbate ratio on adsorbed amount

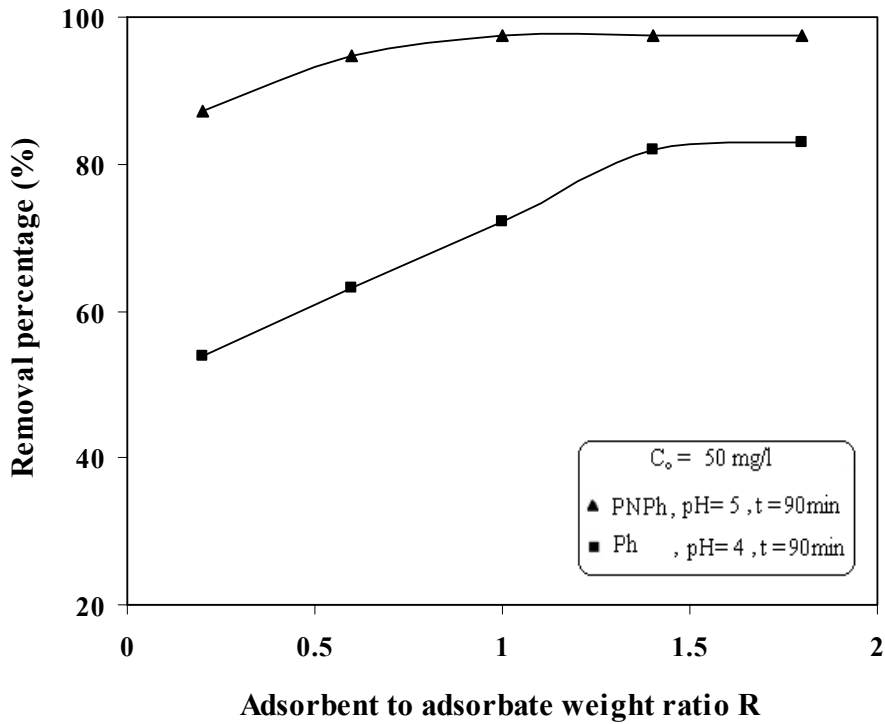


Fig. 5, Effect of adsorbent to adsorbate ratio on removal percentage

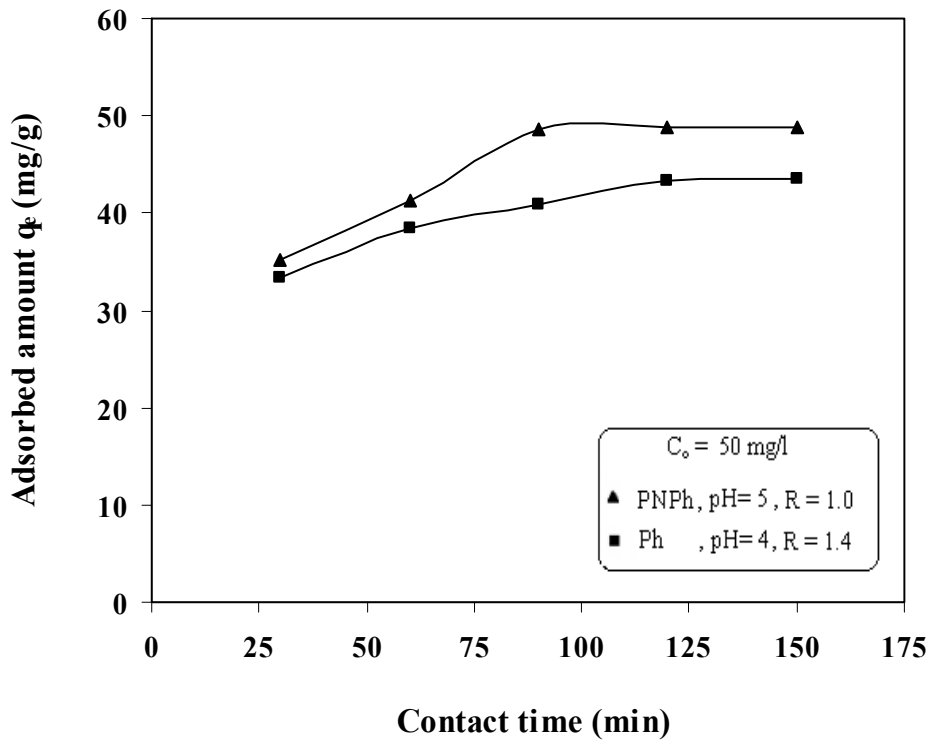


Fig. 6, Effect of contact time on adsorbed amount

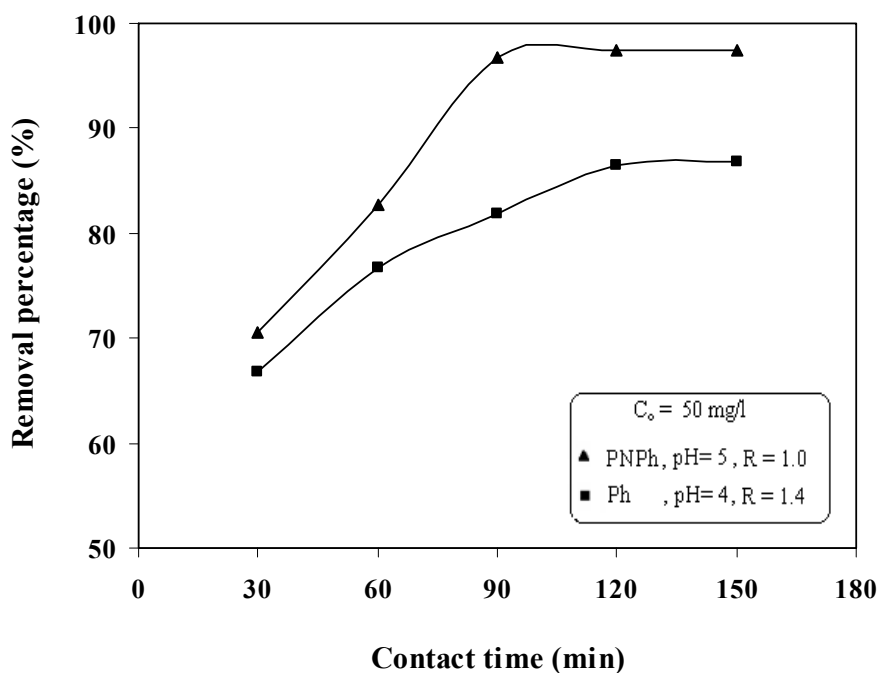


Fig. 7, Effect of contact time on removal percentage

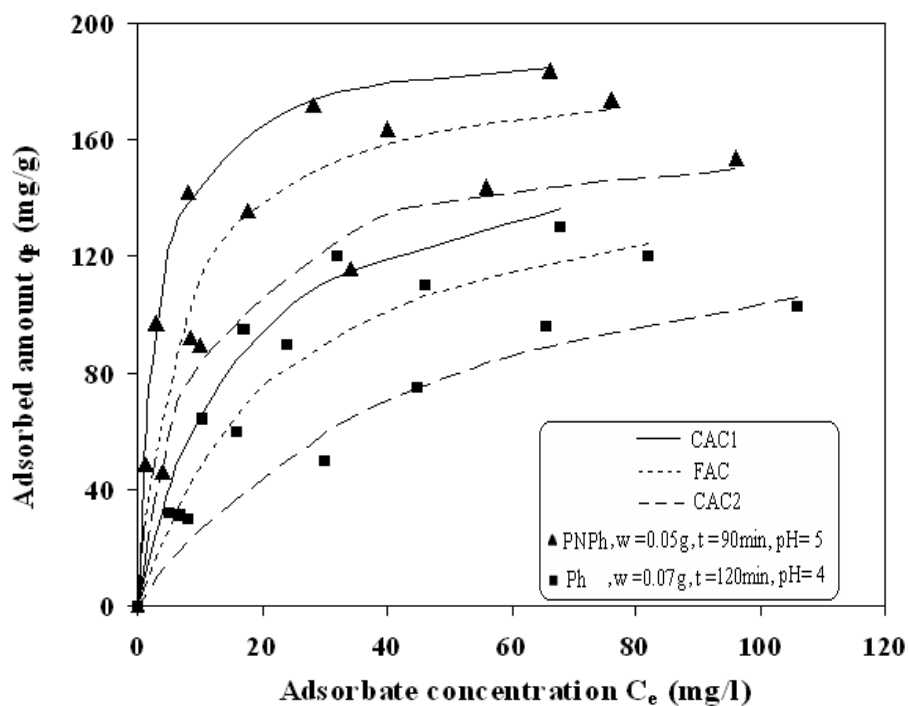


Fig. 8, Equilibrium isotherm of Ph and PNPPh adsorption on activated carbons samples correlated with Langmuir equation

**Table 1, Characteristics of activated carbons samples .**

Characteristic	FAC	CAC1	CAC2
bulk density (g/ml)	0.271	0.454	0.529
surface area (m <sup>2</sup> /g)	780.06	1080.11	555
ash content (%)	8.62	4.24	8.80
moisture content (%)	15.54	11.57	3.51
pH	6.5	7.3	7
conductivity (μs/m)	290	370	330
iodine number (mg/g)	761.40	1047.54	552

**Table 2, Equilibrium isotherm results**

Ph and PNPh isotherm results correlated with Langmuir equation				
adsorbate	adsorbent	q <sub>m</sub> (mg/g)	B (l/mg)	R <sup>2</sup>
Ph	FAC	159.27	0.0436	0.985
	CAC1	167.97	0.0637	0.980
	CAC2	152.68	0.0212	0.974
PNPh	FAC	185.84	0.1472	0.979
	CAC1	193.77	0.3109	0.997
	CAC2	165.45	0.1011	0.987