A comparative Isothermal and Kinetic Study of the Removal of Lead (II) from Aqueous Solution using different sorbents

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Abstract

This study investigated the performance of activated carbon prepared from date pits (ADP), commercial activated carbon (CAC), and zeolite pellets (ZP) in removing lead from aqueous solution. Batch tests were performed to characterize the equilibrium sorption properties of the sorbents. Factors influencing sorption such as contact time, initial pH of the solution, adsorbent dosage, agitation speed, and initial concentration of contaminant have been studied. The sorption data for Pb^{+2} obtained by batch experiments, have been subjected to the Langmuir, and Freundlich isotherm models. The results showed that the Freundlich isotherm model described well the sorption of contaminant for all sorbent materials. The maximum lead sorption capacities q (mg/g) were measured for the three sorbents and it was found that ADP is more effective for removal of Pb (II) than CAC, and ZP from aqueous solution with q(mg/g) equal to 24.625, 12.125, and 4.45 mg/g for ADP, CAC, and ZP, respectively. The kinetic data were analyzed using various kinetic models particularly pseudo-first-order, pseudo-second-order, and intraparticle diffusion.The pseudo-first-order kinetic model was found to agree well with the experimental data for ADP, and CAC, while for ZP the pseudo-second-order kinetic model agree well with the experimental data.The intraparticle diffusion was the rate-controlling step in the sorption process using ADP and CAC, while the intraparticle diffusion was not the rate-controlling step in the sorption process using ZP, with rate constants K_d of 3.459, 1.592, and 0.45 mg g^{-1} $min^{-0.5}$ for ADP, CAC, and ZP, respectively.

Keywords:Sorption; Lead; Adsorbents; Isotherm; Kinetic

1. Introduction

The problems of the ecosystem are increasing with developing technology. Heavy metal pollution is one of the main problems Consequently, removal of heavy metals from wastewater and industrial waste has become a very important environmental issue[4]. The presence of heavy metal ions (such as cobalt (Co), copper (Cu), nickel (Ni), chromium (Cr), mercury (Hg), lead (Pb), cadmium (Cd), zinc (Zn)) in the environment has been a matter of major concern due to their toxicity to human life (e.g. Pb can be caused depression, lethargy, neurologic signs, and thirst). Unlike organic pollutants, these metals will not degrade into harmless end products and they are detected in the waste streams from different industrial activities [15]. Because of their high solubility in the aquatic environments, heavy metals can be adsorbed by living organism. Once they enter the food chain, large concentrations of heavy metals may accumulate in the human body. Therefore, it is necessary to treat metal contaminate wastewater prior to its discharge to the environment[18] One of the most widely and quickly spreading problems in the field of servicing and preservation of water resources is water pollution with heavy metals. It is carefully associated with various human activities such as mining, petroleum industry, metal treatment industry, and power industry, also the high exhaust emissions in urban regions from automobile, burning of domestic, and hospital wastes [11]. Rapid development in the various industries has influence on the environment of surface water via the releasing aconsiderable quantities of these metals. Also, the groundwater can be polluted with hazardous metals by the leaching from the soil after rainfall, and snow [5]. Lead being very toxic metal, located at a second position in the list of prioritized hazardous substances issued by the US Agency for Toxic Substances and Disease Registry [22]. Lead can be used as an intermediate in several industries such as paint and dyes, electroplating, lead acid storage batteries , chemicals products, ceramic industries printing, mine tailings, lead smelting, automobile industry, agricultural runoff, and chemical spills [25,13,1]. Many treatment methods have been used for the treatment of wastewater containing lead ions, among them adsorption has been improved to be an efficient, and economically practical alternative method for treating aqueous solution from metals. Adsorption means a mass transfer process in which substances existing in a liquid phase are accumulated or adsorbed on a solid paricals and thus removed from the liquid. Where the adsorption of liquids occurs on the surface of solid material which has a large surface area per unit mass is called as adsorbent, while the material to be adsorbed on the adsorbent is known as adsorbate [6]. Activated carbons (AC) are known as very effective adsorbents due to their highly developed porosity, large surface area (that can reach 3000 m^2/g), variable characteristics of surface chemistry, and high degree of surface reactivity [8]. However, due to their high production costs, these materials tend to be more expensive than other adsorbents. Currently, there are many studies on the development of low-cost adsorbents, namely by using waste materials for that purpose, most of the AC product particularly from agricultural by-products such as date pits, olive stones, and walnut shells [14], are easily obtainable, inexpensive adsorbents, sustainable and feasibility for deriving wide spectra of activities. Ion exchange is often referred to as exchange adsorption. Exchange adsorption is a process in which ions of one substance of adsorbate concentrates at a surface of adsorbent as a result of electrostatic attraction to charged sites at the surface of the adsorbent. This process is characterized by electrical attraction between the adsorbate and the adsorbent surface [17]. Zeolite use as an ion exchanger for environmentally protection and other applications is stimulated by the good results obtained, the nontoxic nature of these materials, their availability in the many parts of the worlds, and the low cost [7].

The aim of the present work is to investigate the potential application of activated carbon prepared from date pits (ADP) as an inexpensive sorbent material for the removal of lead (Pb^{2+}) from aqueous solution, and comparing its potential with other sorbent materials, which have different removal mechanism (adsorption, and ion exchange) such as commercial activated carbon (CAC) and zeolite pellets (ZP)

2. Experimental work

2.1. Materials

Three materials have been used as sorbents in this work for the removal of lead from aqueous solution

- Date pits (DP) were collected and then manually washed with hot distilled water to remove any other undesirable material. Date pits were oven dried for 24 hrs at 105°C. The dried pits were impregnated with phosphoric acid (85% by weight) at the weight ratio of 1:1(pits:acid). The impregnated stones of 250 g were placed inside a furnace and heated to 500 ^{o} C for 60 min in order to carbonization [19]. After cooling the sample was washed thoroughly using hot distilled water until pH reached to 6.5. Finally, the chemically activated date pits were grinded, and sieved into (1 - 0.6) mm.
- Commercial activated carbon (CAC) supplied by "BDH, ANALAR, England ". CAC was crushed, sieved into (1 - 0.6) mm, and then it was washed before being used with distilled water to remove fine powder and then dried.
- Zeolite pellets (ZP) with size of (1 - 0.6) mm manufactured by "Dwax company for synthetic zeolite" were also used as a reactive materials. The resins were washed with 1M of NaOH and 1M of HCl in order to remove possible organic impurities, and then they washed with distilled water to remove all excess and basic. Finally the resins were dried.

Lead was used as a contaminant had been treated in this study. To prepare a water sample with lead concentration of 1000 mg/l, a 1.5985 g of lead nitrate (manufactured by BDH, England) was dissolved in 1L of distilled water and this solution was kept at room temperature as a stock solution. The pH of this solution was adjusted by adding 0.1 M HNO_3 or 0.1 M NaOH as required.

2.2.Batch Experiments

Batch tests were accomplished in four steps to determine the conditions for the maximum pollutant removal efficiency. These conditions included contact time and initial pH of the solution, adsorbent dosage, agitation speed, and initial lead concentration. The **first step** includes a modification of the solution’s initial pH (3-6) and contact time (0-90 min), (0-120 min), (0-180 min) when using ADP, CAC, and ZP, respectively; but with a fixed initial lead concentration of 50 mg/l, sorbents dosage (0.1, 0.2, 0.5 g/100ml) of ADP, CAC, and ZP, respectively, and agitation speed 200rpm. The **second step** includes changing of sorbents dosage (0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 1, and 2 g/100 ml), (0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 1, and 2 g/100ml), and (0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 1, and 2 g/100ml) of ADP, CAC, and ZP, respectively, with a pH and contact time chosen from the consequence of the first step. Lead concentration and agitation speed were remained as the same of a previous values. The **third step** includes changing in the agitation speed (0, 50, 100, 150, 200, 250, and 300 rpm) with a selection sorbent dosage from the outcomes of the second step. Other parameters were remained at their second step values. Finally, the **last step** includes changing the solution's initial lead concentration (50, 100, 150, 200, and 250 mg/L) with a selection agitation speed from the results of the preceding step; other parameters were remained as the same of the third step values.

In the above-mentioned tests, 250-mL flasks were used, and filled with 100 mL of lead solution with sorbent dosage were placed. Agitation of the flasks was accomplished by an orbital shaker. At the end of any test, a 20-mL solution sample was withdrawn from the flask and then filtered using a filter paper type (Wattmann No. 1and Teknik No. 1) for lead solution, to extract the sorbent materials, and then (10 ml) of the solution was analysis to calculate the concentration of the residual contaminant. The analysis were carried out using atomic absorption spectrophotometer (AAS) (Shimadzu , Japan). However, the efficiency of removal (%) was measured as follows:

$$R = \left[\frac{(Co-Ce)}{Co}\right] \times 100 \quad (1)$$

Where Ce and Co are the equilibrium, and initial concentrations, respectively. R is the removal efficiency (%).

3.Description of sorption data

Two isotherm models were used for the characterization of sorption data[16]:

- Langmuir model: assumes symmetric energies of sorption onto the surface and no migration of sorbate in a plane of the surface. The equation is written as follows:

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

Where q_m is the maximum sorption capacity (mg/g) and b is the constant depended to the free energy of sorption (l/mg).

- Freundlich model: is quantified by:

$$q_e = K_F C_e^{1/n} \quad (3)$$

Where K_F is the Freundlich sorption coefficient and n is an empirical coefficient mention to the intensity of the sorption.

4.Kinetic models

Kinetic sorption models are helpful to understand the mechanism of the sorption process of heavy metals onto ADP, CAC and ZP. These models include pseudo first-order, pseudo second-order and intra-particle diffusion:

- **The pseudo-first order kinetic rate equation is [27]:**

$$\left(\frac{dq_t}{(q_e - q_t)}\right) = K_1 dt \quad (4)$$

Where K_1 is the rate constant of pseudo first order sorption (min^{-1}), q_e is the quantity of contaminant sorbed at equilibrium (mg/g), and q_t the quantity of contaminant sorbed at time t (mg/g). Integrating equation (4) for the boundary conditions t = 0 to t=t and q_t=0 to q_t=q_e and rearranging leads to the linear time-dependent function.

$$\log(q_e - q_t) = \log q_e - (K_1/2.303)t \quad (5)$$

q_e and K_1 can be determined from the slope and intercept of the plot of log(q_e-q_t) against t, respectively, However, if the intercept $(q_e)_{theoretical}$ does not equal $(q_e)_{experimental}$, then the reaction is not favorable to be first-order, irrespective to the correlation coefficient value.

- **The pseudo-second order kinetic rate equation is[8]:**

$$\left(\frac{dq_t}{d_t}\right) = K_2(q_e - q_t)(q_e - q_t)^2 (6)$$

Where K_2 is the rate constant of pseudo second order sorption (g mg^{-1} min^{-1}). The integrated form of Equation (6) canbe rearranged to obtain Equation (7) with the boundary conditions t=0 to t=t and q_t=0 to q_t=q_e:

$$\frac{t}{q_t} = \left(\frac{1}{K_2 q_e 2}\right) + \left(\frac{t}{q_e}\right) \quad (7)$$

the plot of (t/q_t) and t of Equation (7) gives a linear relationship, q_e and K_2 can be determined from the slope and intercept of the plot, respectively.

- **The intraparticle diffusion model [24]:** was considered in order to determine the participation of this process in the sorption of lead ion by ADP, CAC and ZP. According to this model, the plot of uptake (q_t), versus the square root of time ($t^{1/2}$) should be linear if intraparticle diffusion is involved in the overall sorption mechanism. Furthermore, if this line passes through the origin then the intraparticle diffusion is the rate-controlling step of the process [11]. The initial rate of intraparticle diffusion, K_d, can be calculated in the following way:

$$q_t = k_d t^{1/2} \qquad (8)$$

where q_t is the amount of sorbate on the surface of the sorbent at time t (mg/g), K_d is the intraparticle rate constant (mg g^{-1} $min^{1/2}$) that can be obtained from the slope of the straight line of plot q_t versus $t^{1/2}$,and t is the time (min).

5. Results and discussion

5.1.Influence of batch operating parameters

5.1.1. Effect of contact time and initial pH of solution

Fig.1(a,b,c) indicate the effect of contact time and initial pH of solution on lead sorption using 0.1, 0.2, and 0.5 g of ADP, CAC and ZP, respectively, added to 100mL of lead solution in a batch tests at 25°C. obviously, at first of contact time the sorption rate was so fast and increasing until reaching to equilibrium time. This is due to the largest amount of lead relates to the sorbent at the first time of sorption process. The equilibrium means that the lead removal curves against time are smooth and continuous leading to saturation, proposition the likely monolayer encasement of lead on the surface of the sorbent [23]. It is known that lead is in the form of M^{+2}. The increase in the lead removal as the pH increases can be expound by minimizing the competition between proton and lead for the surface sites.When the pH value increased, the removal efficiency will be reduced due to the formation of soluble hydroxyl compounds $pb(OH)^+$ [21]. It is clear from Fig.1 (a,b,c) that the ultimate removal efficiency of lead was accomplished at an initial pH of 6 in (50, 60, and 120min) of contact time for ADP, CAC, and ZP respectively.

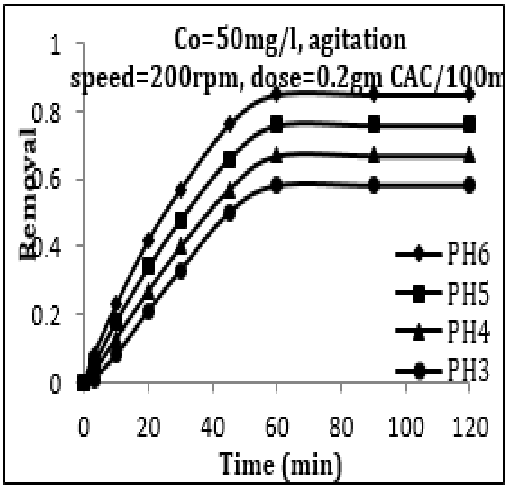

Fig.1a. Removal efficiency of lead on ADP as a function of contact time and initial pH

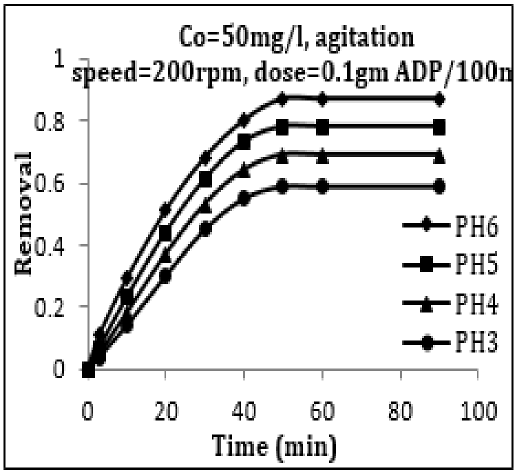

Fig.1b. Removal efficiency of lead on CAC as a function of contact time and initial pH.

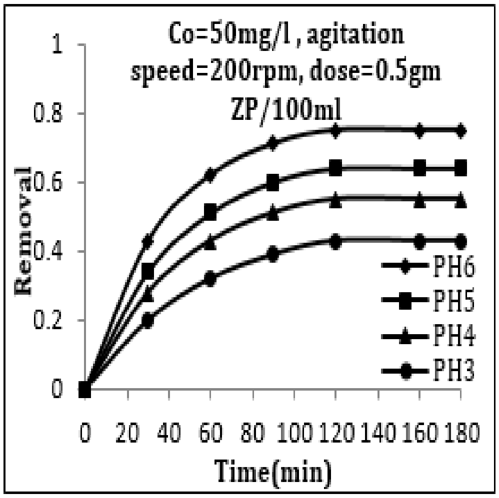

Fig.1c. Removal efficiency of lead on ZP as a function of contact time and initial PH.

5.1.2. Effect of Adsorbents Dosage

One of the important parameters that highly affect the sorption ability is the sorbent dosage. The effect of sorbent dosage on the removal of Pb(II) ions was presented in **Fig. 2**. The effect of different doses of ADP, CAC, and ZP was investigated using 50 mg/L initial concentration of metal, at initial pH 6, contact time (50, 60, and 120 min) of ADP, CAC, and ZP, respectively, and agitation speed = 200 rpm. The results shows an increase in removal efficiency of lead with the increase in dose of the sorbent up to a proven limit and then it will be remains constant. Increase the amount of sorption with increasing dose of sorbent is a rational manner because the increasing of sorbent dosage means a greater number of sorption sites and, then, the removal efficiency of contaminant will be increased [2]. The proportional increase in the removal efficiency of lead ions is not effect after a certain dosages 0.2, 0.4, 1 g/100ml of ADP, CAC, and ZP, respectively, which is fixed as the optimum dose. The data obviously shows that the ADP is more effective than CAC and ZP, with removal efficiency reached to 98% , 97%, and 85% of three sorbents, respectively.

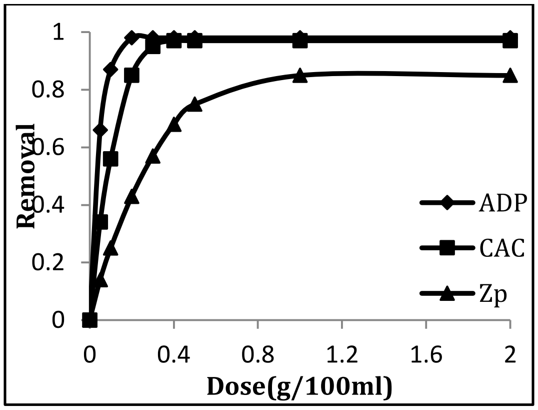

Fig. 2. Effect of ADP, CAC, and ZP dosage on removal efficiencies of lead.

5.1.3.Effect ofAgitation Speed

Fig.3 shows that the percentage removal of lead before shaking (agitation speed= 0) at a about (13, 9, and 8%) when using ADP, CAC, and ZP, respectively. There is a gradual increase in lead sorption when agitation speed increases from 0 to 200 rpm at which about 98% and 97% of lead is removed when using ADP and CAC, respectively. While using ZP lead to 89% of lead was removed when agitation speed increases from 0 to 250. This can be refer to improving the diffusion of lead at the surface of the reactive medium and, then, more contact between binding sites and lead in the aqueous solution [3].

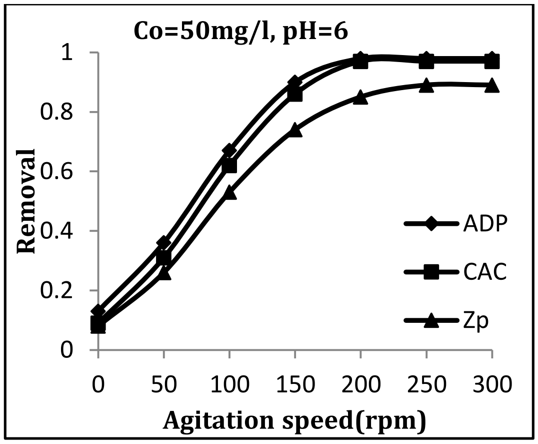

Fig.3. Effect of agitation speed on percentage removal of lead, (0.2g ADP/100ml at t=50min, 0.4g CAC/100ml at t=60min, and 1g ZP/100ml at t=120min)

5.1.4. Effect of Initial lead Concentration

Fig.4 shows that the removal efficiency of lead decreases from (98 to 62%, 97 to 60%, and 89 to 56%) for ADP, CAC, and ZP respectively, when increasing the initial concentration from 50 to 250 mg/L. This trend represents saturation of the active sites available on the sorbents for interaction with contaminant. These results indicate that less favorable sites became involved with increasing lead concentrations in the aqueous solution[19].

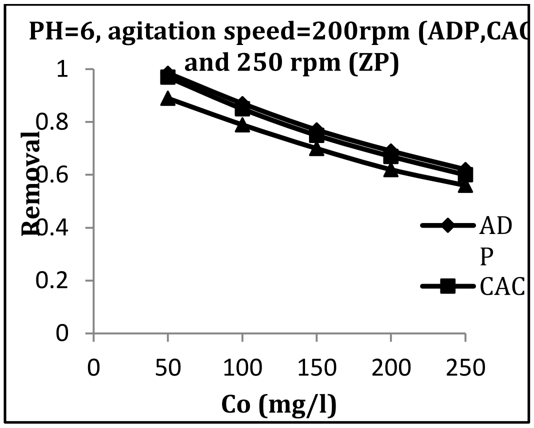

Fig.4. Effect of initial concentration on removal efficiency of lead (0.2g ADP/100ml at t=50min, 0.4g CAC/100ml at t=60min, and 1g ZP/100ml at t=120min).

5.2. Sorption isotherms

The sorption data for lead ions on the ADP, CAC, and ZP are adjusted with a linearized form of Freundlich and Langmuir models adopted here **Table. 1** offer the adjusted parameters and coefficient of determination (R^2) for each model. The experimental data conform well to the Freundlich model for (ADP, CAC, and ZP), and with good correlation coefficients of 0.995,0.9971, and 0.9959 for ADP, CAC and ZP, respectively as shown in **Fig. 5** (a,b,c).

Table. 1 Parameters of isotherm models for the sorption of lead onto ADP, CAC, and ZP.

Isotherm model	Parameter	ADP	CAC	ZP
Langmuir	b (l/mg) q_m (mg/g) R^2	0.111 83.33 0.9831	0.1 40 0.9837	0.0514 16 0.9904
Freundlich	K_F (mg/g)(l/mg)$^{1/n}$ n R^2	23.93 3.968 0.9950	10.66 3.72 0.9971	2.375 2.61 0.9959

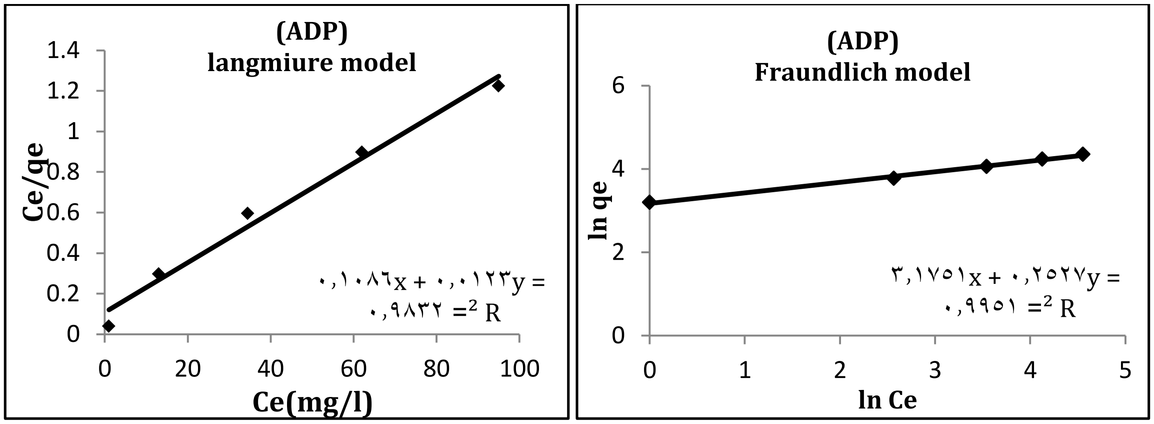

Fig.5.5a Linear form of isotherm models for sorption of Pb^{+2} onto ADP (dose = 0.2g/100ml , pH = 6 , agitation speed = 200 rpm , contact time=50min).

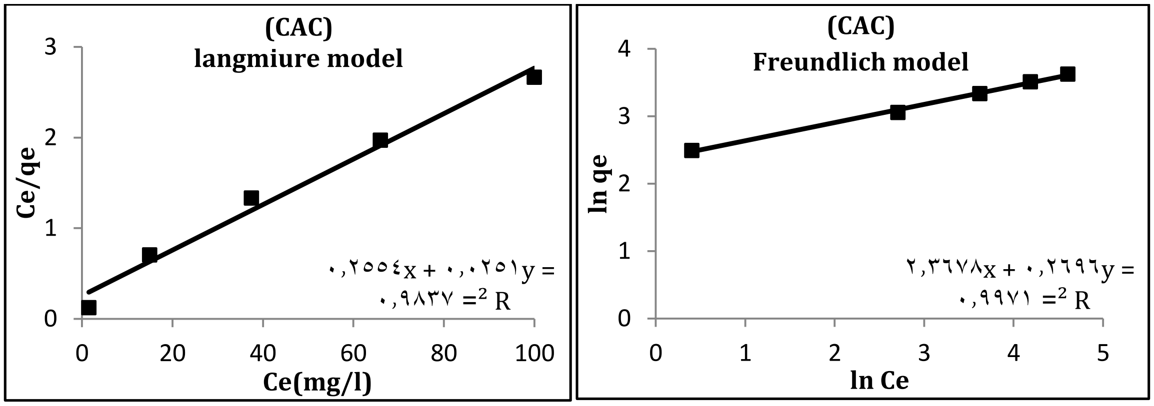

Fig.5.5b Linear form of isotherm models for sorption of Pb^{+2} onto CAC (dose=0.4 g/100 ml, pH=6, agitation speed=200 rpm, contact time=60min).

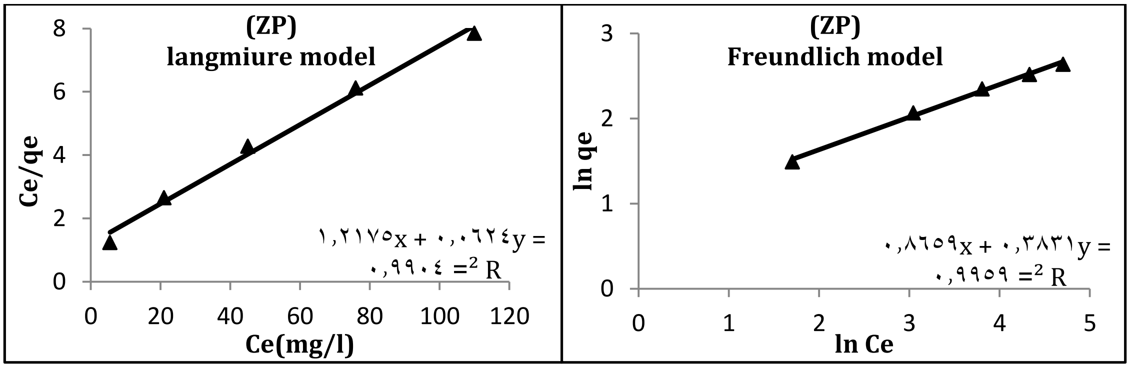

Fig.5.5c Linear form of isotherm models for sorption of Pb^{+2} onto ZP(dose=1g/100 ml, pH=6, agitation speed=250 rpm, contact time=120min).

5.3. The physicochemical properties of the adsorbents

The physicochemical properties of the adsorbents were measured by Oil Research and Development Center-Ministry of Oil,**Table. 2**

Table. 2 Physical and chemical characteristics of ADP, CAC, and ZP.

Materials	Physical prosperities		Chemical prosperities	
ADP	Surface area(m^2/g)	950	PH	6.5
	Bulk density(gm/cm^3)	0.251	Ash content (%)	4.88
	Porosity	0.46	C %	54.9
	Average particle diameter (mm)	0.775	Moisture content %	7
	pore volume (cm^3/g)	0.921	Volatile matter (%)	5
CAC	Surface area(m^2/g)	800	PH	7.5
	Bulk density(gm/cm^3)	0.147	Ash content (%)	< 5
	Porosity	0.46	C %	68.6
	Average particle diameter (mm)	0.775	Moisture content %	7.8
	pore volume (cm^3/g)	0.76	Volatile matter (%)	1.7
ZP	Surface area(m^2/g)	520	PH	7.5
	Bulk density(gm/cm^3)	0.58	SiO_2	34.48
	Porosity	0.46	Al_2O_3	29.93
	Average particle diameter (mm)	0.775	CaO	2.54
	Cation exchange capacity (meq/100g)	1.7	Na_2O	0.51

5.4.Fourier transform infrared analysis

FTIR analysis is a direct means form investigating the sorption mechanisms by distinguish the functional groups accountable for binding of Pb^{+2} onto ADP as the best sorbent material in compared with CAC and ZP . Infrared spectra of ADP samples before and after sorption of Pb^{+2}were examined using (SHIMADZU FTIR, 800 series spectrophotometer) in the department of Chemical science at University of Nahrain [26]. These spectra were measured within the range 400–4,000cm^{-1} as shown in **Fig.6**. The infrared spectrum and functional groups assigned for sorption were summarized in **Table 3:**

Table. 3 Functional groups responsible for lead sorption onto ADP.

Wave NO. (cm^{-1})	Type of bond	Functional group
537.02	$C-Br^-$	Alkyl halides
645.73	$C-Br^-$	Alkyl halides
741.82	$C-Cl^-$	Alkyl halides
1150.26	$C-O-C^-$	Alcohols
3725.53	$-OH^-$	Carboxylic acid

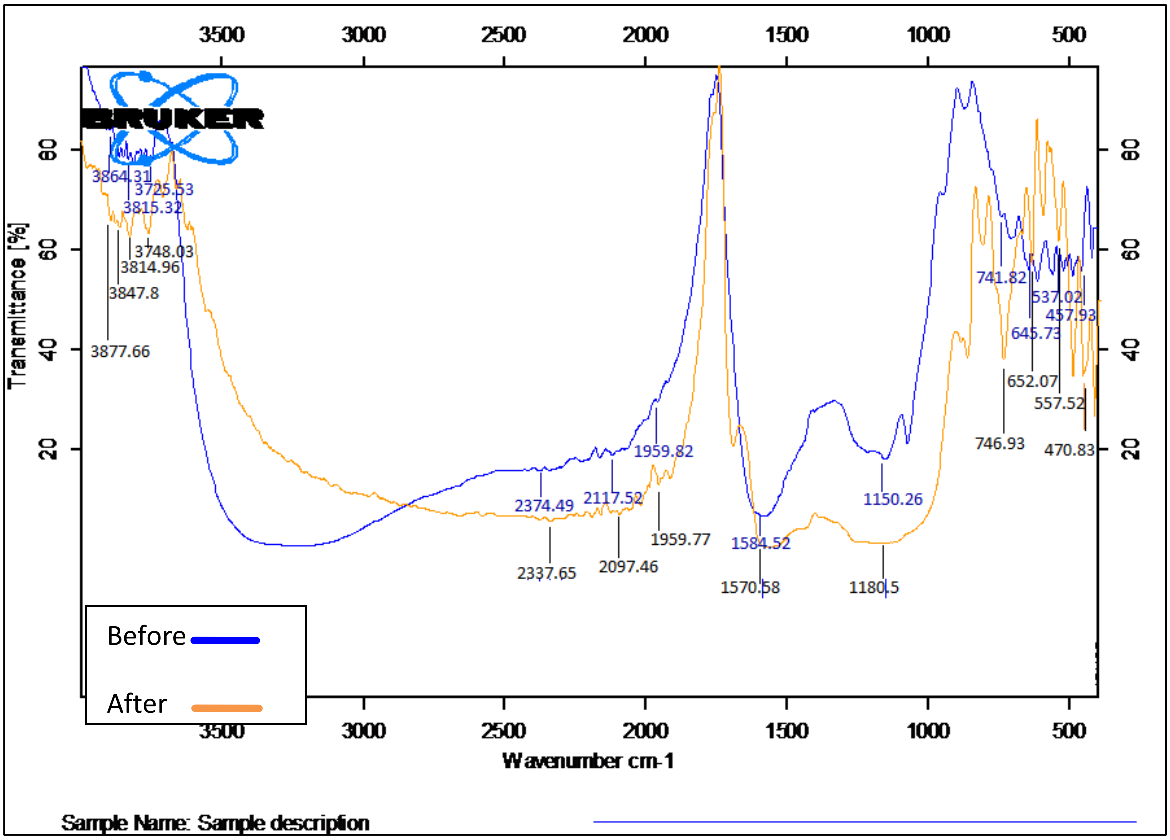

Fig. 6 FTIR analysis of ADP before and after sorption of lead

5.5. kinetic study

It is clear from **Fig. 7** and **Table. 4** that the reactions for ADP, and CAC are being first order because that the values of q_e(experimental) and q_e(calculated) are close, irrespective to the amount of the (R^2) correlation coefficient, so the mechanisms will be physical adsorbtion. While for ZP the reaction is being second order which means that the mechanism will be chemo sorpion

Fig. 8 shows a plot of the intraparticle diffusion model for the sorption of lead ions onto ADP, CAC, and ZP, respectively. As shown in Fig. 8 the plots of uptake (q_t), against the square root of time (t) for ADP and CAC were linear, which referred that the intraparticle diffusion was the rate-controlling step in the sorption of Pb^{+2} for ADP, and CAC, while for ZP was nearly not linear, which referred to that the intraparticle diffusion was not the rate-controlling step in the sorption systems for ZP. The values of the rate constant K_d are 3.459 , 1.592 , and 0.45 mg $g^{-1}min^{-0.5}$, which gives indication about the mobility of the Pb^{2+} toward the ADP, CAC, and ZP surface, respectively, as tabulated at Table 4.

Table. 4 The kinetics constants for the sorption of Pb (II) onto ADP, CAC, and ZP.

Adsorbent	**q_e(mg/g), Exp.**	**pseudo-first-order**	**pseudo-second- order**	**Intra-particle diffusion**
ADP	24.5	K_1 (min)$^{-1}$ 0.051 $q_{e,(calc.)}$(mg/g) 23.12 R^2 0.973	K_2(mg $g^{-1}min^{-1}$) 0.00153 $q_{e.(calc.)}$(mg/g) 33.33 R^2 0.982	K_d(mg $g^{-1}min^{-0.5}$) 3.459 R^2 0.9983
CAC	12.125	K_1 (min)$^{-1}$ 0.041 $q_{e,(calc.)}$(mg/g) 11.12 R^2 0.99	K_2(mg $g^{-1}min^{-1}$) 0.0029 $q_{e,(calc.)i}$(mg/g) 16.13 R^2 0.99	K_d(mg $g^{-1}min^{-0.5}$) 1.592 R^2 0.9946
ZP	4.45	K_1 (min)$^{-1}$ 0.044 $q_{e,(calc.)}$(mg/g) 6.44 R^2 0.974	K_2(mg $g^{-1}min^{-1}$) 0.004 $q_{e,(calc.)}$ (mg/g) 6.2 R^2 0.971	K_d(mg $g^{-1}min^{-0.5}$) 0.45 R^2 0.908

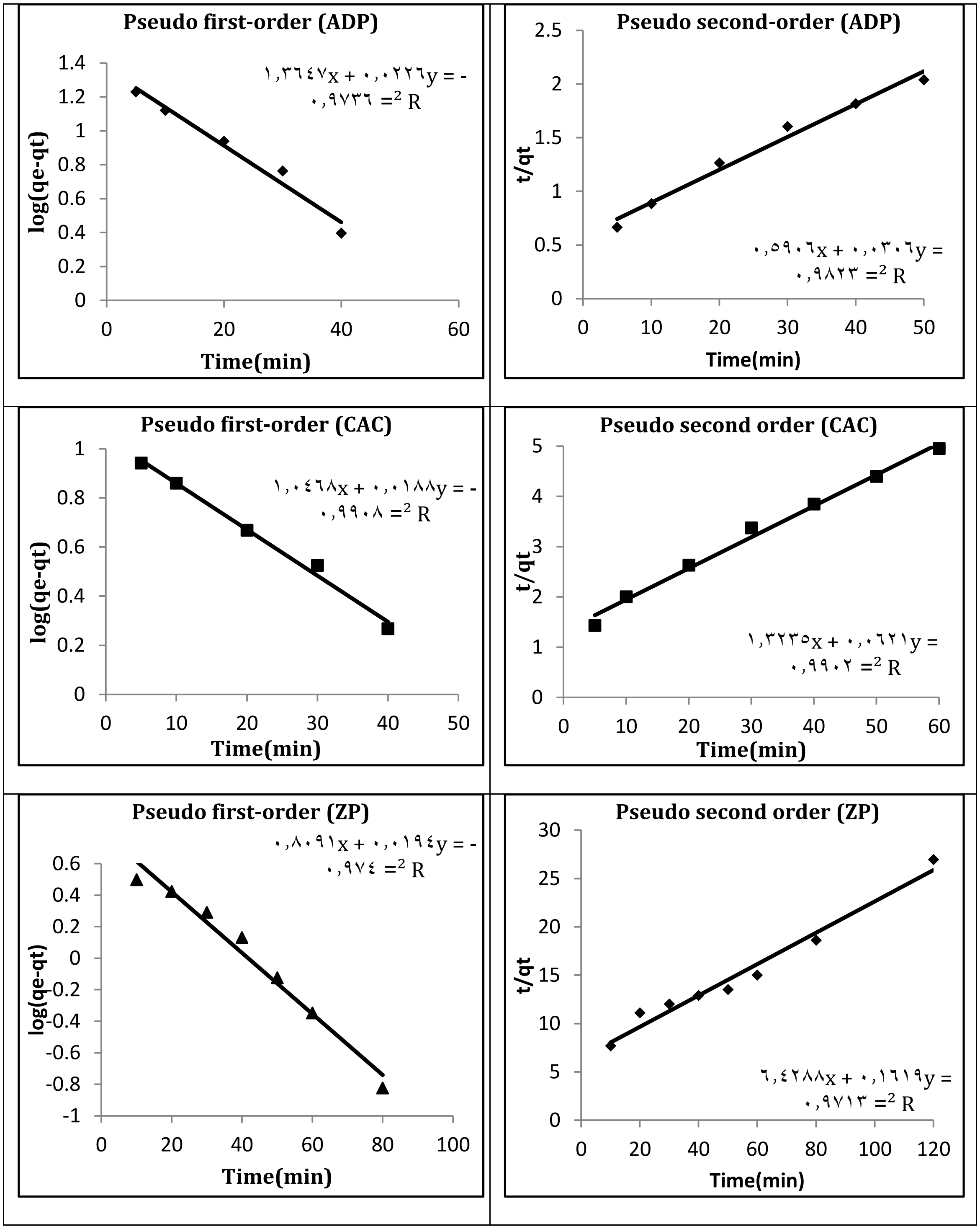

Fig.7 Pseudo-first and second order plot for sorption of Pb (II) onto ADP, CAC, and ZP

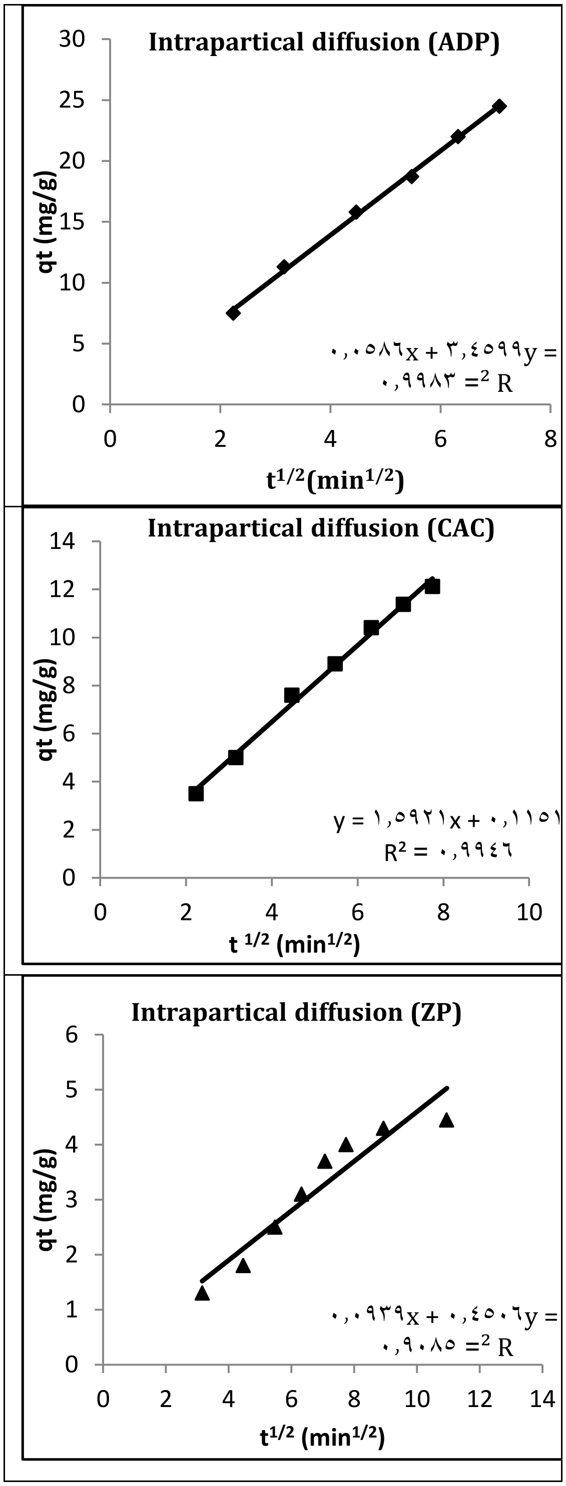

Fig. 8 Plot of the amount of Pb^{+2}sorbed onto ADP, CAC, and ZP vs. square root of t.

5.6. Conclusion

Sorption of Pb(II) on ADP, CAC, and ZP, was investigated. The experiments have shown that:

1. It was found that ADP is more effective for removal of Pb (II) than CAC, and ZP from aqueous solution, the maximum sorption capacities for ADP, CAC, and ZP were 24.5, 12.125, and 4.45 mg/g, respectively.
2. The percentage removal was dependent on the contact time, initial pH of the solution, adsorbent dosage, agitation speed, and initial concentration of contaminant.
3. The isotherm study refers that the sorption data correlated well with Freundlich for ADP, CAC, and ZP.
4. The kinetic data for ADP, and CAC showed that the pseudo-first-order kinetic model was conform better than pseudo-second-order kinetic model, while ZP followed well to the pseudo-second-order kinetic model, these results show that physical adsorption have been predominant in the sorption of Pb(II) ions on ADP, and CAC, while chemo sorption was prevailing for ZP. The intraparticle diffusion was the rate-controlling step in the sorption

process using ADP and CAC, while the intraparticle diffusion was not the rate-controlling step in the sorption process usingZP, with rate constants K_d of 3.459, 1.592, and 0.45 mg $g^{-1}min^{-0.5}$ for ADP, CAC, and ZP, respectively.

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Notations	
AAS	Atomic absorption spectrophotometer
ADP	Activated date pits
b	Constant depended to the free energy of sorption (l/mg).
CAC	Commercial activated carbon
C_e	Equilibrium concentration (mg/l).
FTIR	Fourier transfer infrared spectroscopy
K_1	Rate constant of pseudo first order adsorption (min^{-1})
K_2	Rate constant of pseudo second order adsorption ($g\ mg^{-1}\ min^{-1}$)
K_d	Intraparticle rate constant ($mg\ g^{-1}\ min^{-1/2}$)
K_F	Freundlich sorption coefficient $(mg/g)(l/mg)^{1/n}$
n	Empirical coefficient mention to the intensity of the sporption
q_e	Amount of solute removed from solution (mg/g).
q_m	maximum sorption capacity (mg/g)
q_t	Amount of contaminant sorbed at time t (mg/g)

R^2	Coefficient of determination.
Rpm	Revolution per minute.
t	Time (min.)
ZP	Zeolite pellets

المقارنة بين نماذج الايسوثرم والدراسة الحركية لأزالة أيونات الرصاص من محلول مائي بأستخدام مواد ماصة مختلفة

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الخلاصة

تهدف الدراسة الحالية الى معرفة إمكانية استخدام كلاً من الكربون المنشط المحضر من نوى التمر، الكربون المنشط التجاري، وكريات الزيولايت لأزالة الرصاص من المحلول المائي. في اختبارات الدفعة تم دراسة تاثير عدة متغيرات تشغيلية مثل زمن التماس بين ايونات الرصاص والمواد الماصة، الدالة الحامضية، كمية المواد الماصة، سرعة الرج، والتركيز الابتدائي للملوث. أضهرت نتائج الامتزاز ان نموذج فريندلتش هو الافضل تمثيلاً لبيانات الامتزاز من نموذج لانكمير و لجميع المواد المَازة. تم قياس السعة القصوى لامتصاص الرصاص حيث وجد ان ال ADP هو الاكثر فعالية من ال CAC وال ZP وكانت تساوي 24.5، 12.125، و 4.45 (ملغ\غم) ل ADP و CAC و ZP على التوالي. تم تحليل البيانات الحركية باستخدام نماذج حركية مختلفة وهي النموذج الحركي ذو المرتبة الاولى، النموذج الحركي ذو المرتبة الثانية، ونموذج الانتشار داخل الجسيمات. وقد وجد ان النموذج الحركي ذو المرتبة الأولى متفق بشكل جيد مع البيانات التجريبية ل (CAC),(ADP) ، بينما وجد النموذج الحركي ذو المرتبة الثانية متفق بشكل جيد مع البيانات التجريبية لل (ZP). وكان نموذج الانتشار داخل الجسيمات هو معدل التحكم على الخطوة في عملية الامتصاص بأستخدام (CAC) و (ADP) في حين لم يكن الانتشار داخل الجسيمات هو معدل التحكم على الخطوة في عملية الامتصاص باستخدام (ZP) مع ثوابت المعدل (Kd) 3.459، 1.592، 0.45 ملغ.غم$^{-1}$.دقيقة$^{-0.5}$ ل (ZP),(CAC),(ADP) على التوالي.

الكلمات المفتاحية:الامتصاص; الرصاص; المواد الماصة ; الايسوثرم ; الحركية.