

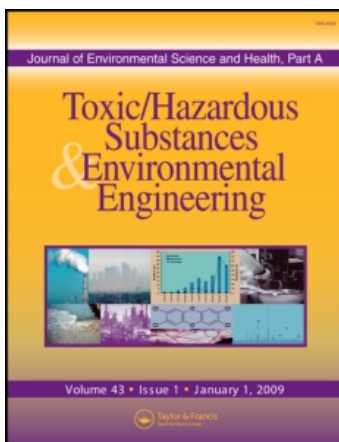
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### Comparative sorption kinetic studies of dye and aromatic compounds onto fly ash

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**COMPARATIVE SORPTION KINETIC STUDIES OF DYE AND AROMATIC COMPOUNDS ONTO FLY ASH**

Key Words: Fly ash, kinetics, sorption, dye, *o*-cresol, *p*-nitrophenol

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**ABSTRACT**

A pseudo-second order and a pseudo-first order mechanism for the sorption of Omega Chrome Red ME as well as *o*-cresol and *p*-nitrophenol onto fly ash have been compared. Intraparticle diffusion processes and chemical sorption processes for the sorption also have been studied. The batch data for the sorption of Omega Chrome Red ME, *o*-cresol and *p*-nitrophenol onto fly ash have been analysed to predict the rate constant of sorption based on the assumption of a pseudo-second order mechanism. The equilibrium capacity and initial sorption rate have also been determined to study the effect of initial solute concentration and temperature on the sorption process. An activation energy of sorption has also been evaluated using the pseudo-second order rate constants.

## INTRODUCTION

The sorption of heavy metals, dyes and organic compounds from waste water by fly ash has been extensively studied in the literature. However, although the adsorption kinetics of individual compounds onto fly ash have been investigated, the mechanistic processes which occur are not completely understood, for instance, the mechanism of sorption. Traditionally, the kinetics have been described by the pseudo-first order Lagergren equation and intraparticle diffusion was investigated. Panday et al. (1985) reported that the adsorption of copper by fly ash is diffusion controlled. In the case of chrome dye, Gupta et al. (1988) reported that the intraparticle diffusion is not the only rate controlling step but the rate controlling step is mainly intraparticle diffusion. Also Khare et al. (1987) reported that the uptake of Victoria Blue by fly ash is diffusion controlled and the results fit a first order kinetic equation. Singh and Rawat (1994) reported that sorption of phenolic compounds on fly ash is a first order reaction and intraparticle diffusion is the rate-limiting step. Dasmahapatra et al. (1996), carried out studies on the separation characteristics of hexavalent chromium from aqueous-solution by fly-ash. They proposed the reaction kinetics of separation follows first-order kinetics more satisfactorily at higher temperature.

The properties of fly ash are extremely variable and depend on factors such as the type of coal (bituminous, sub-bituminous and lignite coal), degree of pulverization, flame temperature, method of collection and storage of fly ash (Kapoor and Viraraghavan, 1996). From these results, the difference in sorption capacities is believed to be largely due to the lime content of the fly ash. However, an attempt has been made to explain the kinetics and

mechanism of sorption in this study by comparing three mechanistic models:

- (i) pseudo-first order kinetic model, (ii) pseudo-second order kinetic model and
- (iii) intraparticle diffusion model.

### MATERIALS AND METHODS

The experimental data discussed and analysed by the pseudo-second order kinetic mechanism proposed in this papers have been reported previously in the literature. The sorption of *o*-cresol and *p*-nitrophenol onto fly ash by Singh and Rawat (1994) and the sorption of Omega Chrome Red ME dye onto fly ash by Gupta et al. (1988).

### RESULTS AND DISCUSSION

The rate constants from the three models have been compared to explain the sorption mechanism. A simple kinetic analysis of sorption is the pseudo first-order rate expression of Lagergren in the form:

$$\log(q_1 - q_t) = \log(q_1) - \frac{k_1}{2.303}t \quad (1)$$

where

$k_1$  is the rate constant of pseudo-first order sorption, (1/min),

$q_1$  is the amount of solute sorbed at equilibrium, (mg/g),

$q_t$  is amount of solute sorbed on the surface of the fly ash at any time,  $t$ , (mg/g).

A pseudo-second order rate expression based on sorption equilibrium capacity may be represented in the form:

$$\frac{dq_t}{dt} = k_2(q_e - q_t)^2 \quad (2)$$

On integration this becomes:

$$\frac{1}{(q_e - q_t)} = \frac{1}{q_e} + k_2 t \quad (3)$$

where

$q_e$  is the amount of solute sorbed at equilibrium, (mg/g),

$k_2$  is the rate constant of second order sorption, (g/mgmin).

The intraparticle diffusion rate parameter is expressed in terms of the square root of time and sorption capacity in the following form:

$$q_t = k_i t^{0.5} \quad (4)$$

where

$k_i$  is a rate constant of diffusion (mg/gmin<sup>0.5</sup>).

#### Effect of Initial Solute Concentration

Figures 1 and 2 show the effect of agitation time on the removal of *p*-nitrophenol (PNP), *o*-cresol (OCL) and Omega Chrome Red ME (OCRME) by fly ash. The results show that an increase in the initial aromatic compounds and dye concentrations produces a reduction in the percentage removal of the aromatic compounds and dye from the water. The removal of OCRME decreases from 98.7 to 69.1% with an increase of initial OCRME concentration from 5 to 20 mg/dm<sup>3</sup> after 120 min. The percentage removal of PNP and OCL also decreases with an increase in the initial aromatic compound concentrations. The removal decreases from 39.8 to 27.8% for PNP and 16.6 to 13.2% for OCL with an increase of initial concentration from 250 to 500

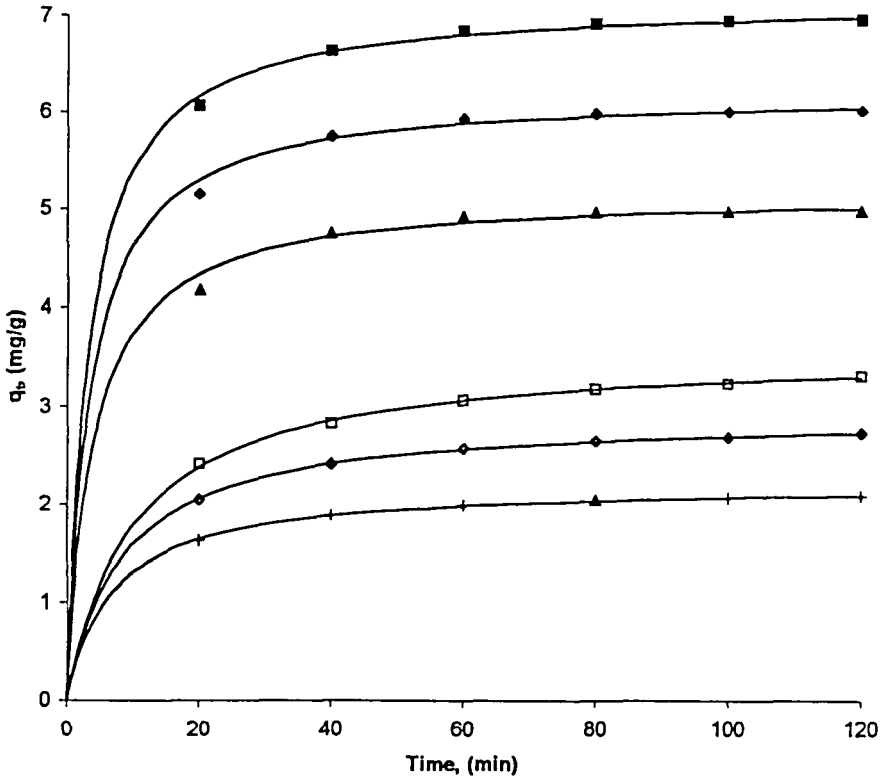


FIGURE 1

Effect of Initial *p*-Nitrophenol and *o*-Cresol Concentrations. Symbols: PNP Experimental Data ■ 500 mg/dm<sup>3</sup>, ◆ 350 mg/dm<sup>3</sup>, ▲ 250 mg/dm<sup>3</sup>; OCL Experimental Data □ 500 mg/dm<sup>3</sup>, ◇ 350 mg/dm<sup>3</sup>, △ 250 mg/dm<sup>3</sup>; - Second Order Model.

mg/dm<sup>3</sup>. The rate constants, obtained from the plots of equations (1), (3) and (4), are shown in Table 1. Figures 3 and 4 shows plots of the linearised form of the model in equation (3) for the sorption of PNP and OCRME onto fly ash at different initial PNP and OCRME concentrations. Figures 5 and 6 show the linearised form of the pseudo-first order and the pseudo-second order models for the sorption of OCRME onto fly ash. The correlation coefficients,  $r_2^2$ , and

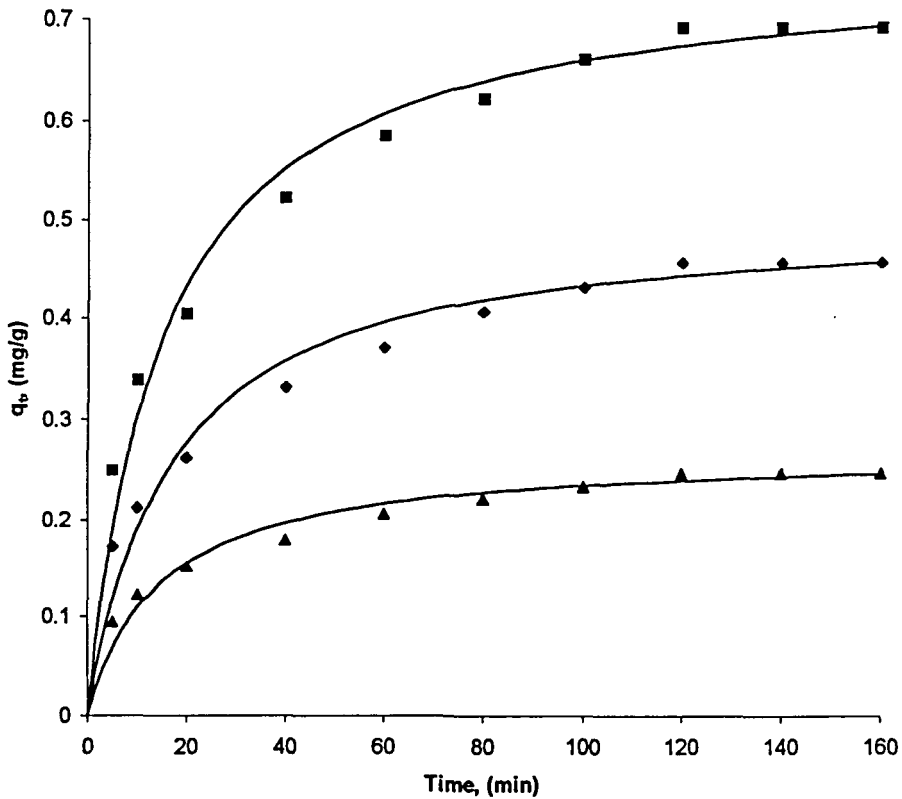


FIGURE 2

Effect of Initial Concentration of Omega Chrome Red ME. Symbols: Experimental Data ■ 20 mg/dm<sup>3</sup>, ◆ 10 mg/dm<sup>3</sup>, ▲ 5 mg/dm<sup>3</sup>; - Second Order Model.

the pseudo-second order rate parameters,  $k_2$ , and the correlation coefficients,  $r_1^2$ , and the first order rate parameters,  $k_1$ , are shown and compared with  $r_i^2$  and  $k_i$  values for the intraparticle diffusion based model. The data show a good compliance with the pseudo-second order equation and the regression coefficients for the linear plots were higher than 0.992 for all the systems in these studies. The correlation coefficients,  $r_1^2$ , for the pseudo-first order model are greater than in the case of the pseudo-second order equation.

**TABLE 1**  
**A Comparison of Rate Parameters of Initial Solute Concentration**

	$C_0$	$r_2^2$	$q_e$	$k_2$	H	$r_1^2$	$k_1$	$r_i^2$	$k_i$
PNP	250	1.000	5.16	$5.15 \times 10^{-2}$	1.37	0.787	$1.56 \times 10^{-2}$	0.757	0.113
	350	1.000	6.20	$4.76 \times 10^{-2}$	1.83	0.819	$1.58 \times 10^{-2}$	0.779	0.121
	500	1.000	7.16	$4.31 \times 10^{-2}$	2.21	0.865	$1.59 \times 10^{-2}$	0.819	0.130
OCL	250	1.000	2.20	$6.65 \times 10^{-2}$	0.322	0.926	$1.49 \times 10^{-2}$	0.881	$6.72 \times 10^{-2}$
	350	1.000	2.91	$4.15 \times 10^{-2}$	0.351	0.944	$1.46 \times 10^{-2}$	0.903	$9.95 \times 10^{-2}$
	500	1.000	3.57	$2.79 \times 10^{-2}$	0.356	0.967	$1.43 \times 10^{-2}$	0.934	0.134
OCRME	5	0.996	0.269	0.254	$1.84 \times 10^{-2}$	0.963	$1.41 \times 10^{-2}$	0.958	$1.48 \times 10^{-2}$
	10	0.995	0.503	0.122	$3.10 \times 10^{-2}$	0.965	$1.37 \times 10^{-2}$	0.966	$2.86 \times 10^{-2}$
	20	0.997	0.757	$8.90 \times 10^{-2}$	$5.11 \times 10^{-2}$	0.956	$1.40 \times 10^{-2}$	0.947	$4.28 \times 10^{-2}$

$C_0$ : mg/dm<sup>3</sup>,  $q_e$ : mg/g,  $k_2$ : g/mgmin, h: mg/gmin,  $k_1$ : 1/min,  $k_i$ : mg/gmin<sup>0.5</sup>

However the equilibrium sorption capacity obtained using the intercept of the equation (1) did not give reasonable values suggesting that this sorption process is not a first-order reaction. In addition, the data for the pseudo-first order rate model were only analysed for the first two hours of the sorption process, after this the deviation between the experimental data and the theoretical data increased rapidly as shown in Figures 5 and 10.

Table 1 shows that the pseudo-second order rate constants,  $k_2$ , were found to decrease from  $6.65 \times 10^{-2}$  to  $2.79 \times 10^{-2}$  g/mgmin, for an increase in the initial concentration from 250 to 500 mg/dm<sup>3</sup> for the sorption of OCL and decrease



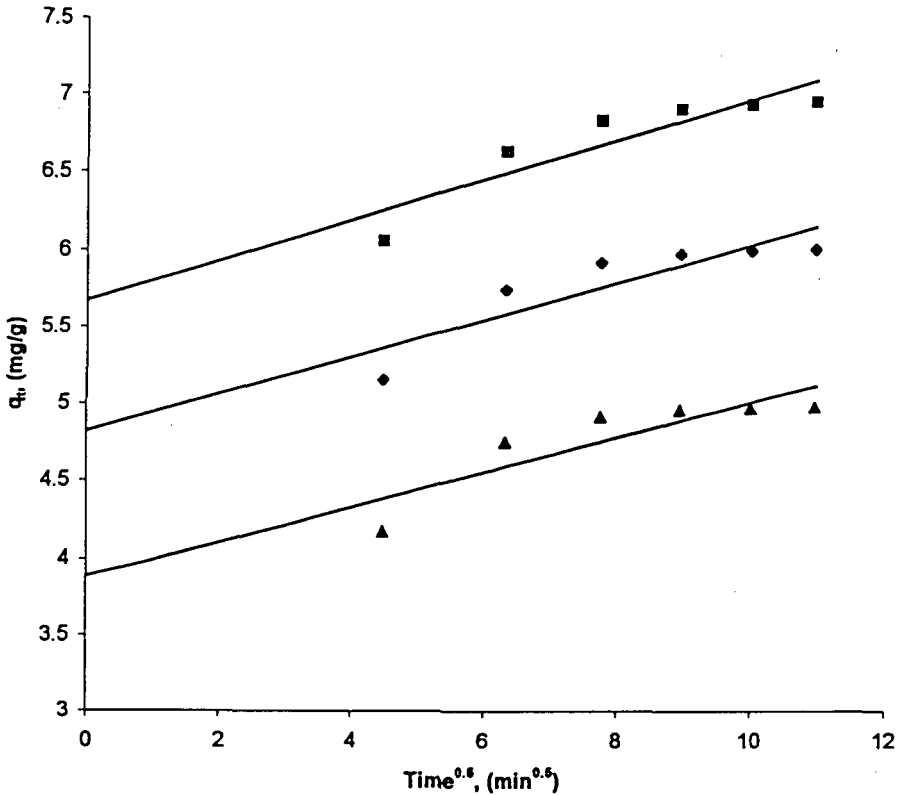


FIGURE 3

Intraparticle Diffusion Kinetics of *p*-Nitrophenol on Fly Ash. Symbols: Experimental Data ■ 500 mg/dm<sup>3</sup>, ◆ 350 mg/dm<sup>3</sup>, ▲ 250 mg/dm<sup>3</sup>; - Intraparticle Diffusion Model.

from  $5.15 \times 10^{-2}$  to  $4.31 \times 10^{-2}$  g/mgmin for PNP. In the case of dye,  $k_2$  values were found to decrease from 0.191 to  $7.86 \times 10^{-2}$  g/mgmin, for an increase in the initial concentration from 5 to 20 mg/dm<sup>3</sup>. The  $k_2$  values for the sorption of OCL are greater than for the sorption of PNP. However, the initial sorption rates for the sorption of PNP were found greater than the sorption of OCL. It suggests that initial concentration has more effect on the initial sorption rate in

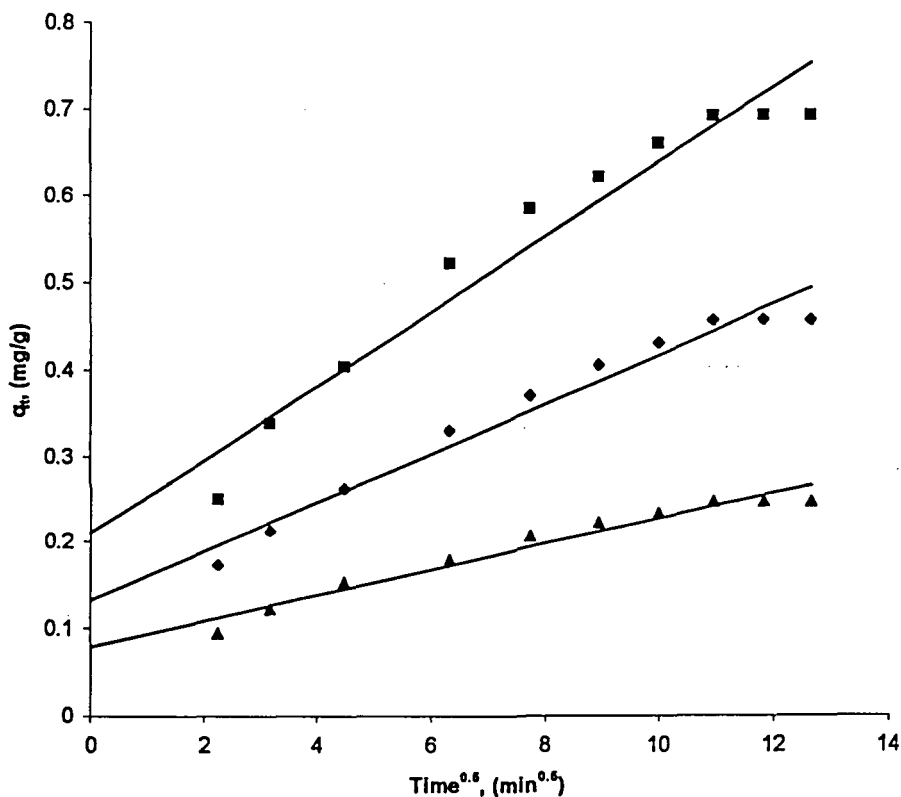


FIGURE 4

Intraparticle Diffusion Kinetics of Omega Chrome Red ME on Fly Ash. Symbols: Experimental Data ■ 20 mg/dm<sup>3</sup>, ◆ 10 mg/dm<sup>3</sup>, ▲ 5 mg/dm<sup>3</sup>; - Intraparticle Diffusion Model.

the case of PNP whereas in the case of OCL of initial concentration has greater effect on the pseudo-second order rate constants.

Effect of Temperature

Figures 7 to 9 show a series of contact time curves for the solution temperature ranging from 30 to 50°C for PNP, OCL and OCRME respectively. The contact time experiments can be used to establish the time dependence of

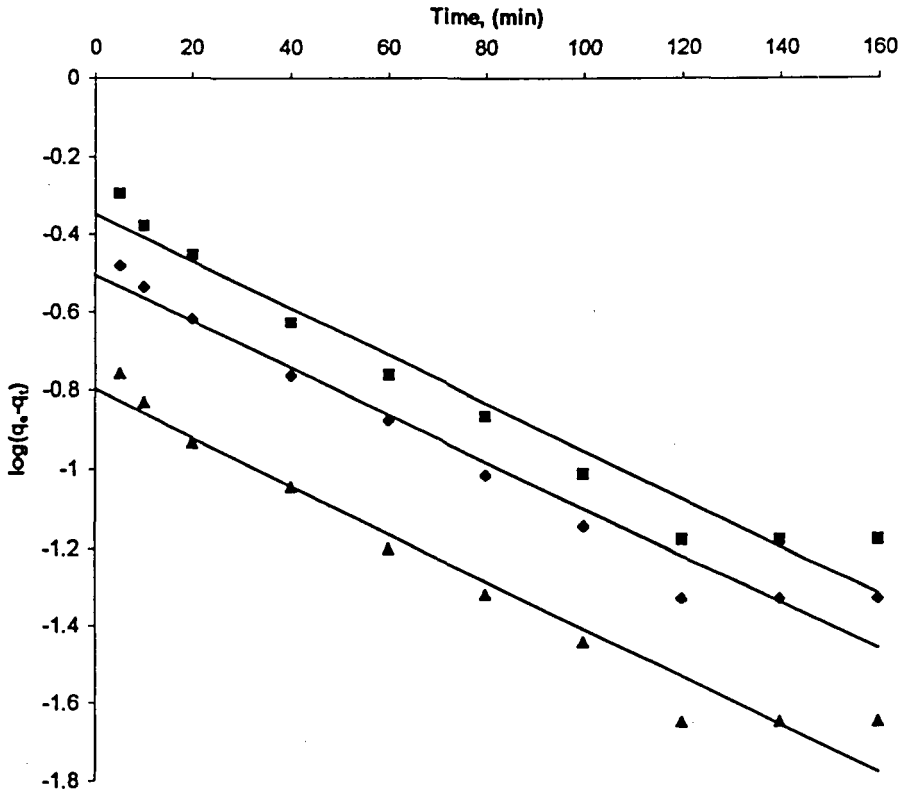


FIGURE 5

First-Order Sorption Kinetics of Omega Chrome Red ME on Fly Ash. Symbols: Experimental Data ■ 20 mg/dm<sup>3</sup>, ◆ 10 mg/dm<sup>3</sup>, ▲ 5 mg/dm<sup>3</sup>; - First Order Model.

the system. The pseudo-first order rate expression may be tested by plotting  $\log(q_e - q_t)$  against time,  $t$ , for the sorption of OCL onto fly ash to obtain the rate parameters (Figure 10). Also a plot of  $t/q_t$  against time,  $t$ , based on the assumption of a pseudo-second order mechanism (Figure 11) and a plot of sorption capacity,  $q_t$ , against time,  $t^{0.5}$ , reveals the extent of intraparticle diffusion influence in the sorption mechanism (Figure 12). A comparison of

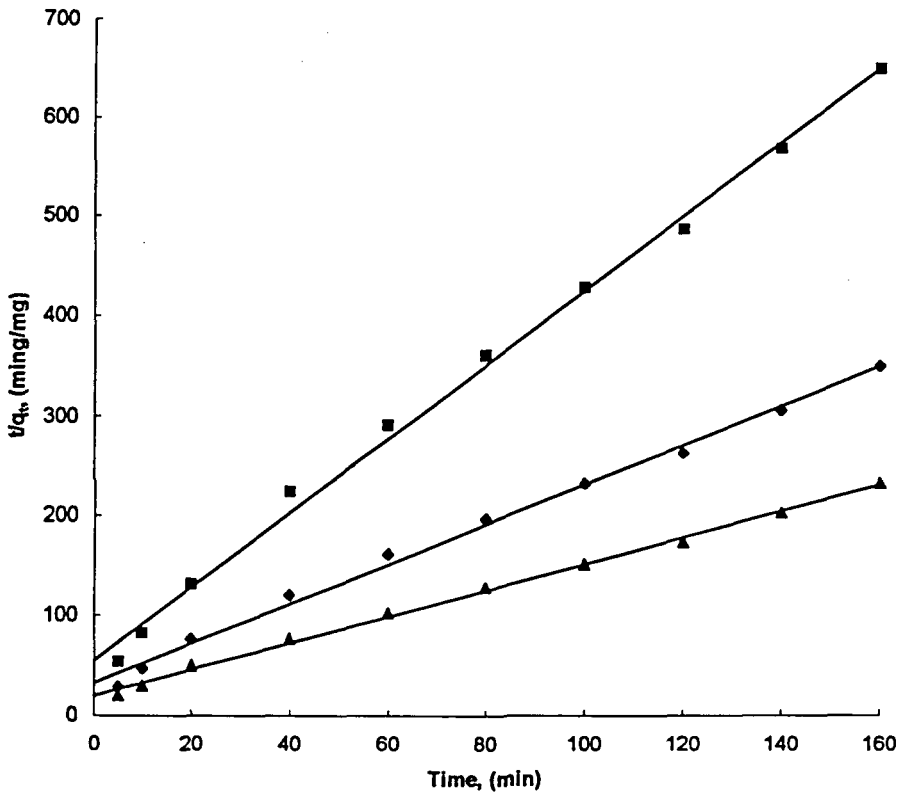


FIGURE 6

Pseudo-Second Order Sorption Kinetics of Omega Chrome Red ME on Fly Ash. Symbols: Experimental Data ■ 20 mg/dm<sup>3</sup>, ◆ 10 mg/dm<sup>3</sup>, ▲ 5 mg/dm<sup>3</sup>; - Second Order Model.

rate parameters,  $k_1$ ,  $k_2$  and  $k_i$  and correlation coefficients  $r_1^2$ ,  $r_2^2$  and  $r_i^2$  are shown in Table 2.

Table 2 shows that the correlation coefficients,  $r_2^2$ , for the pseudo-second order kinetic model are much greater than the correlation coefficients,  $r_1^2$ , for the pseudo-first-order kinetic model and the intraparticle diffusion coefficients,  $r_i^2$ , for the sorption of PNP and OCL onto fly ash, strongly suggesting a

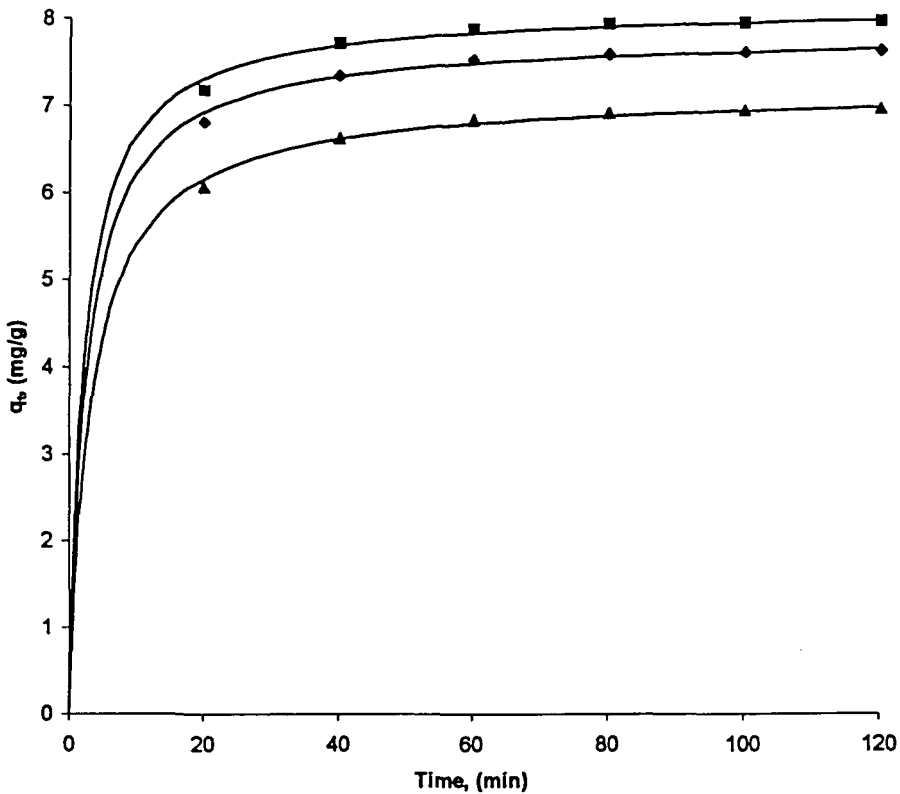


FIGURE 7

Effect of Temperature of *p*-Nitrophenol. Symbols: Experimental Data ■ 50°C, ◆40°C, ▲ 30°C; — Second Order Model.

chemical reaction mechanism. However, in the case of the sorption of the OCRME onto fly ash the pseudo-first order reaction correlation coefficients and the intraparticle diffusion coefficients are all higher than the value of 0.986 with most of the  $r_i^2$  values being higher than 0.990.

Table 2 shows the values of the pseudo-second order rate constant,  $k_2$ , were found to increase from  $4.31 \times 10^{-2}$  to  $5.57 \times 10^{-2}$  g/mgmin, for an increase in

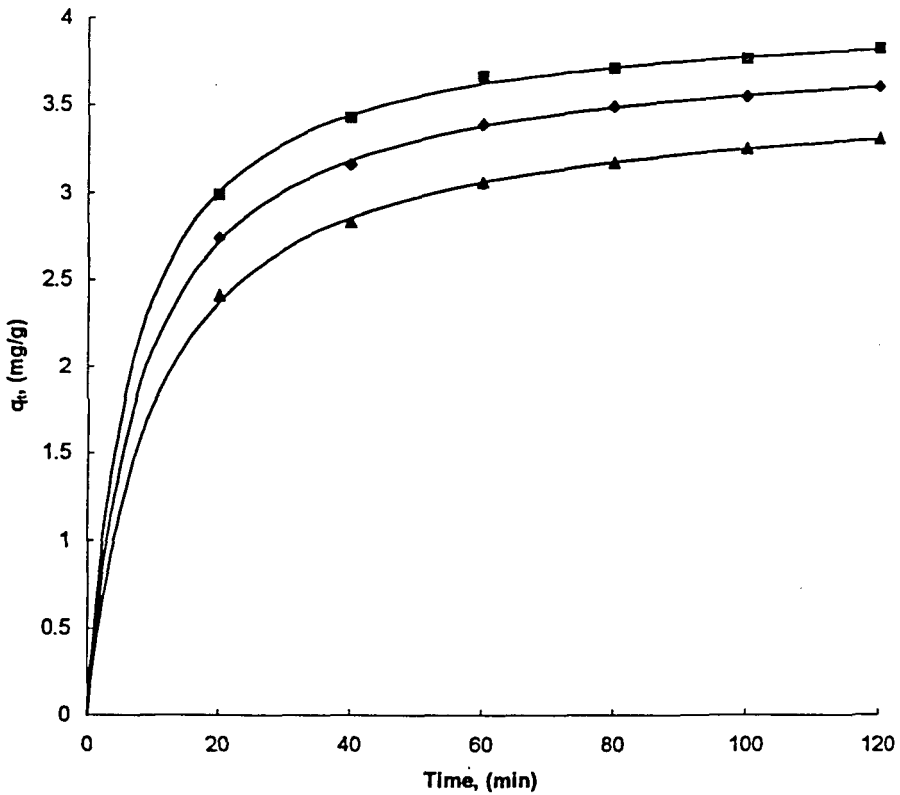


FIGURE 8

Effect of Temperature of *o*-Cresol. Symbols: Experimental Data ■ 50°C, ◆ 40°C, ▲ 30°C; - Second Order Model.

the solution temperature from 303 to 323 K for the sorption of PNP; and from  $275 \times 10^{-2}$  to  $364 \times 10^{-2}$  g/mgmin, for the same increase in solution temperature for the sorption of OCL. However the rate constants of OCRME decreased from 0.109 to 0.101 g/mgmin, for an increase in the solution temperature from 303 to 323 K. The Arrhenius equation can be used to provide a linear relationship between the pseudo rate constant and temperature. Figures 13 to

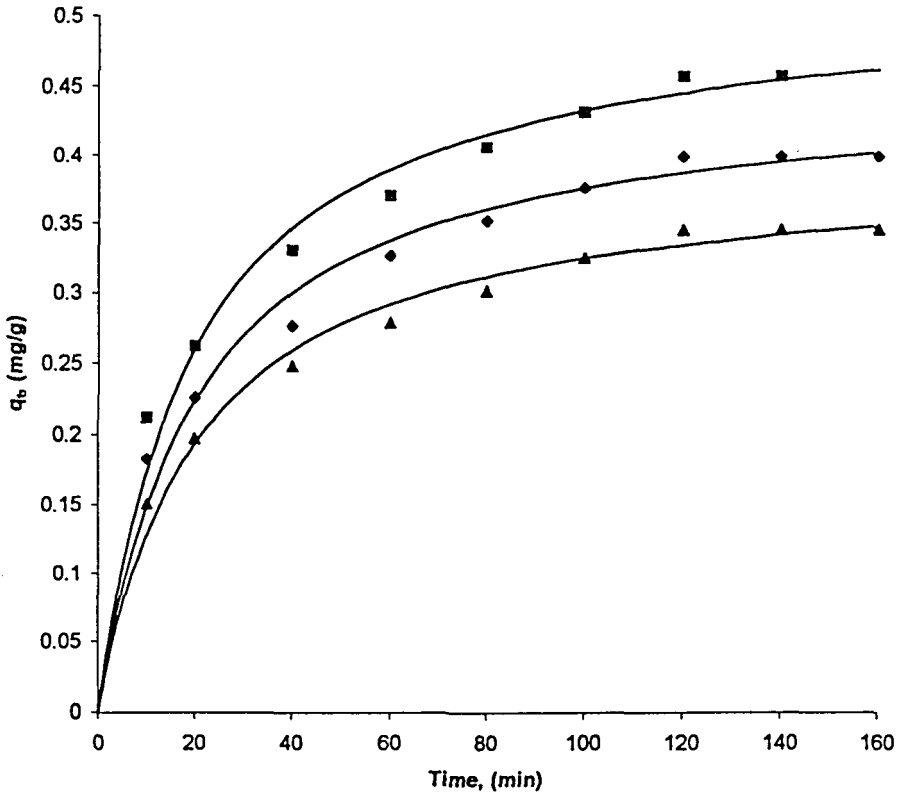


FIGURE 9

Effect of Temperature of Omega Chrome Red ME. Symbols: Experimental Data ■ 50°C, ◆ 40°C, ▲ 30°C; — Second Order Model.

15 show the corresponding linear plots of the values of the pseudo rate constant  $\ln(k_2)$  against  $10^3/T$  and the data were regressed to obtain expressions for these Arrhenius parameter values with correlation coefficients of 0.992, 0.997 and 0.999 for the sorption of PNP, OCL and OCRME respectively onto fly ash. The sorption rate constant is usually expressed as a function of solution temperature by the following Arrhenius type relationship:

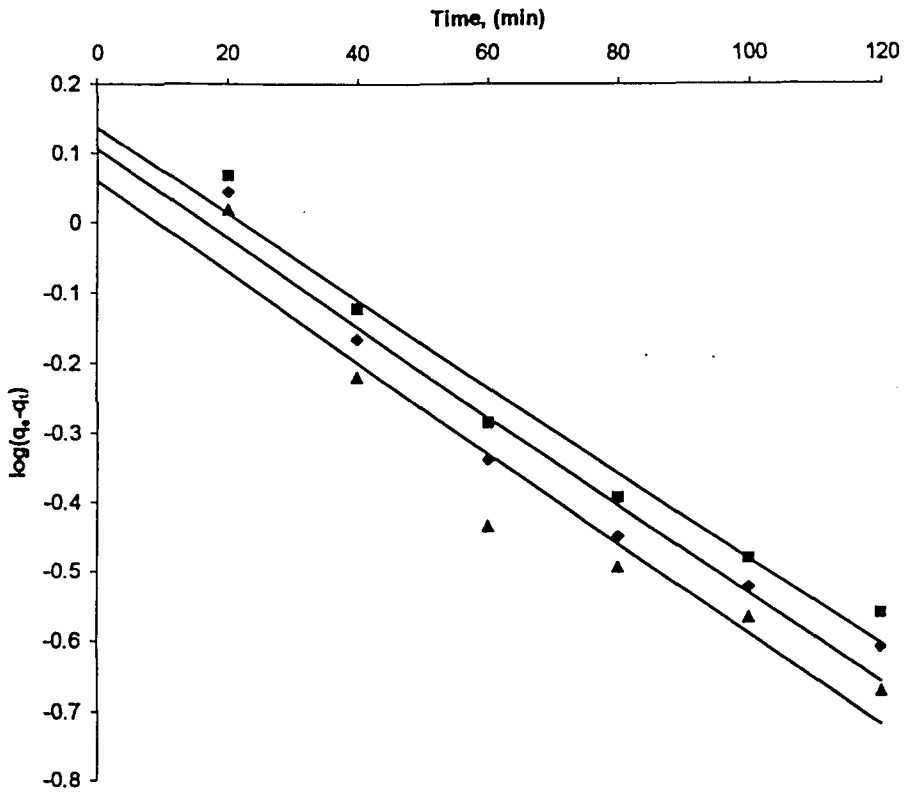


FIGURE 10

First Order Sorption Kinetics of *o*-Cresol on Fly Ash. Symbols: Experimental Data ■ 50°C, ◆ 40°C, ▲ 30°C; - First Order Model.

$$k_2 = k_0 \exp\left(\frac{-E}{RT}\right) \tag{5}$$

where

$k_2$  is the rate constant of sorption, (g/mgmin),

$k_0$  is the temperature independent factor, (g/mgmin),

$E$  is activation energy of sorption, (kJ/mol),



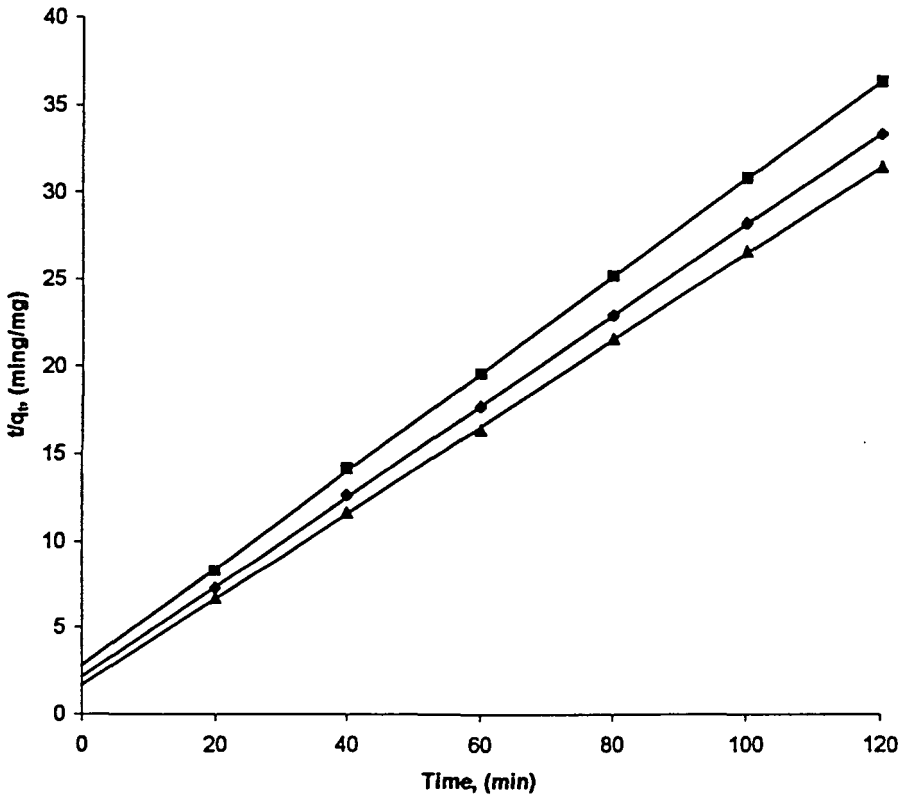


FIGURE 11

Pseudo-Second Order Sorption Kinetics of *o*-Cresol on Fly Ash. Symbols: Experimental Data ■ 50°C, ◆ 40°C, ▲ 30°C; — Second Order Model.

R is the gas constant, (8.314 J/molK),

T is solution temperature, (K).

From this equation the rate constant of sorption,  $k_0$ , is 2.82 g/mgmin for PNP/fly ash, 2.49 g/mgmin for OCL/fly ash and  $3.31 \times 10^{-2}$  g/mgmin for OCREM/fly ash sorption systems. Furthermore, the activation energy of sorption,  $E$ , is 10.5 kJ/mole for PNP/fly ash and 11.4 kJ/mole for the sorption

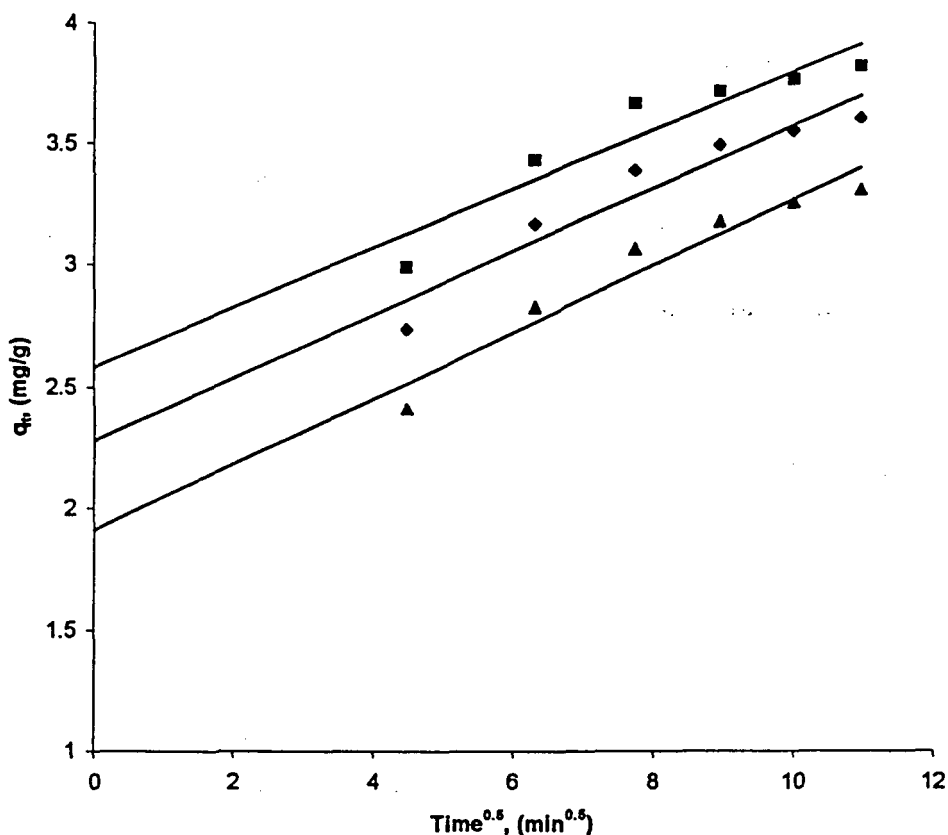


FIGURE 12

Intraparticle Diffusion Kinetics of *o*-Cresol on Fly Ash. Symbols: Experimental Data ■ 50°C, ◆ 40°C, ▲ 30°C; - Intraparticle Diffusion Model.

system of OCL/fly ash. Since sorption is an exothermic process, it would be expected that an increased solution temperature would result in decreased sorption capacity. The sorption of cadmium and chromium on fly ash have also been reported to be exothermic (Viraraghavan and Rao, 1991). However, the activation energy of sorption,  $E$ , is -3.00 kJ/mole for the sorption system of OCRME onto fly ash. This sorption is an endothermic process and

**TABLE 2**  
**A Comparison of Rate Parameters with Temperature**

	T	$r_2^2$	$q_e$	$k_2$	h	$r_1^2$	$k_1$	$r_i^2$	$k_i$
PNP	30	1.000	7.16	$4.31 \times 10^{-2}$	2.21	0.865	$1.59 \times 10^{-2}$	0.819	0.130
	40	1.000	7.81	$5.02 \times 10^{-2}$	3.06	0.846	$1.61 \times 10^{-2}$	0.801	0.117
	50	1.000	8.12	$5.57 \times 10^{-2}$	3.68	0.818	$1.62 \times 10^{-2}$	0.775	0.111
OCL	30	1.000	3.58	$2.75 \times 10^{-2}$	0.353	0.968	$1.42 \times 10^{-2}$	0.937	0.135
	40	1.000	3.85	$3.14 \times 10^{-2}$	0.465	0.957	$1.46 \times 10^{-2}$	0.920	0.129
	50	1.000	4.03	$3.64 \times 10^{-2}$	0.592	0.928	$1.50 \times 10^{-2}$	0.883	0.122
OCRME	30	0.995	0.519	$9.77 \times 10^{-2}$	$2.63 \times 10^{-2}$	0.984	$1.30 \times 10^{-2}$	0.980	$2.91 \times 10^{-2}$
	40	0.996	0.453	0.109	$2.23 \times 10^{-2}$	0.956	$1.17 \times 10^{-2}$	0.962	$2.40 \times 10^{-2}$
	50	0.997	0.392	0.125	$1.92 \times 10^{-2}$	0.956	$1.17 \times 10^{-2}$	0.958	$2.09 \times 10^{-2}$

T: °C,  $q_e$ : mg/g,  $k_2$ : g/mgmin, h: mg/gmin,  $k_1$ : 1/min,  $k_i$ : mg/gmin<sup>0.5</sup>

consequently it would be expected that an increased solution temperature would result in increased sorption capacity. Weber (1967) has stated that, since diffusion is an endothermic process, the rate of sorption will increase with increased solution temperature when intraparticle transport (pore diffusion) is the rate-limiting step.

The corresponding linear plots of the values of  $q_e$  and the initial sorption rate, h, against T were regressed to obtain expressions for these values in terms of temperature with high correlation coefficients. Therefore it is further considered that  $q_e$  and h can be expressed as a function of T for PNP and OCL as follows:

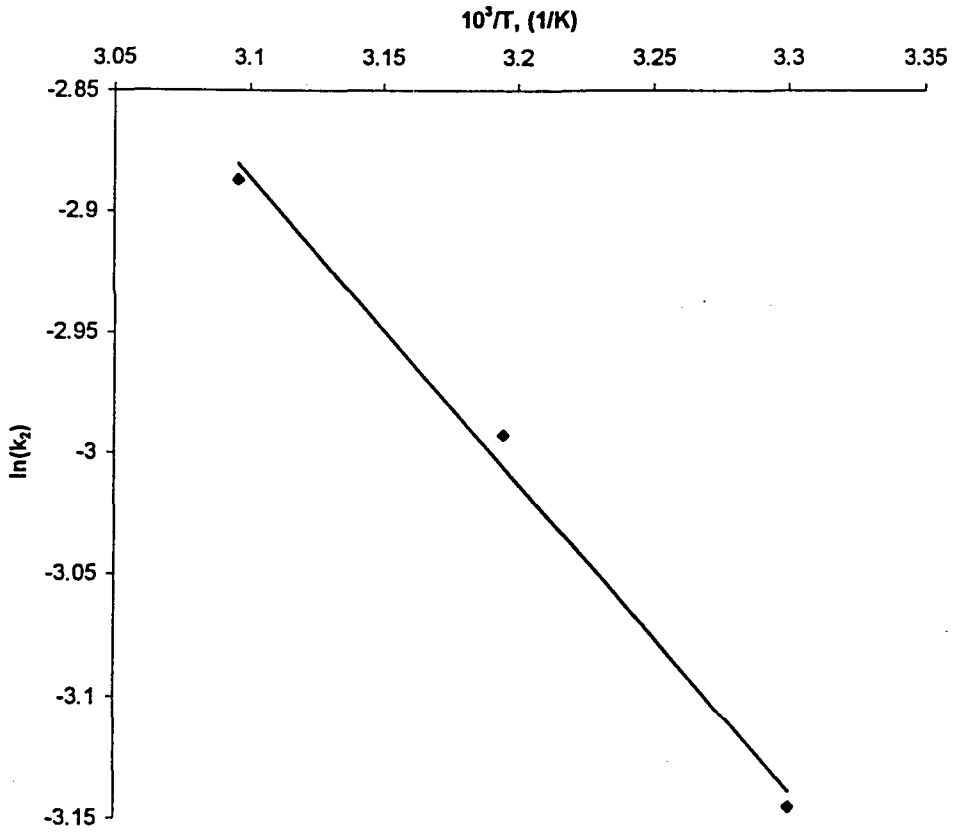


FIGURE 13  
Plot of  $\ln(k_2)$  Versus  $1/T$  for p-Nitrophenol.

$$q_e = \exp\left(\frac{A_q}{T} + B_q\right) \tag{6}$$

and

$$h = \exp\left(\frac{A_h}{T} + B_h\right) \tag{7}$$

Substituting the values of  $q_e$  and  $h$  from Table 3 into equations (6) and (7) and then into equation (3), the rate law for a pseudo-second order and the relationship of  $q_e$ ,  $T$  and  $t$  can be represented as follows:

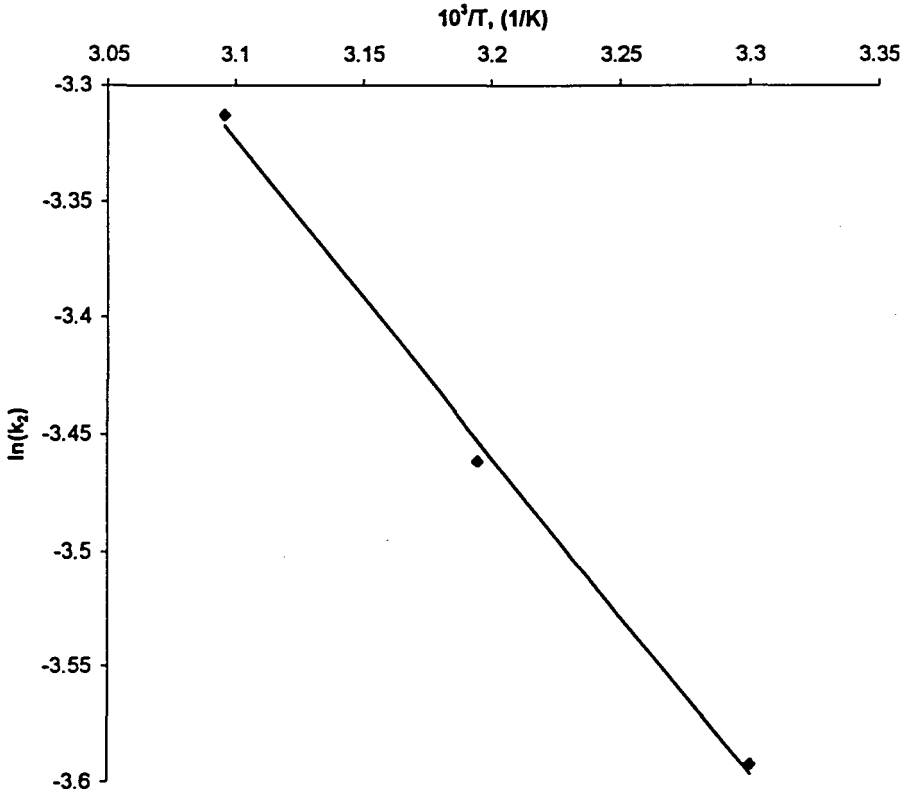


FIGURE 14  
Plot of  $\ln(k_2)$  Versus  $1/T$  for *o*-Cresol.

for PNP:

$$q_t = \frac{t}{\exp\left(\frac{2.50 \times 10^3}{T} - 9.07\right) + \left[\exp\left(\frac{6.18 \times 10^2}{T} - 4.01\right)\right] t} \quad (8)$$

for OCL:

$$q_t = \frac{t}{\exp\left(\frac{2.54 \times 10^3}{T} - 7.33\right) + \left[\exp\left(\frac{5.84 \times 10^2}{T} - 3.21\right)\right] t} \quad (9)$$

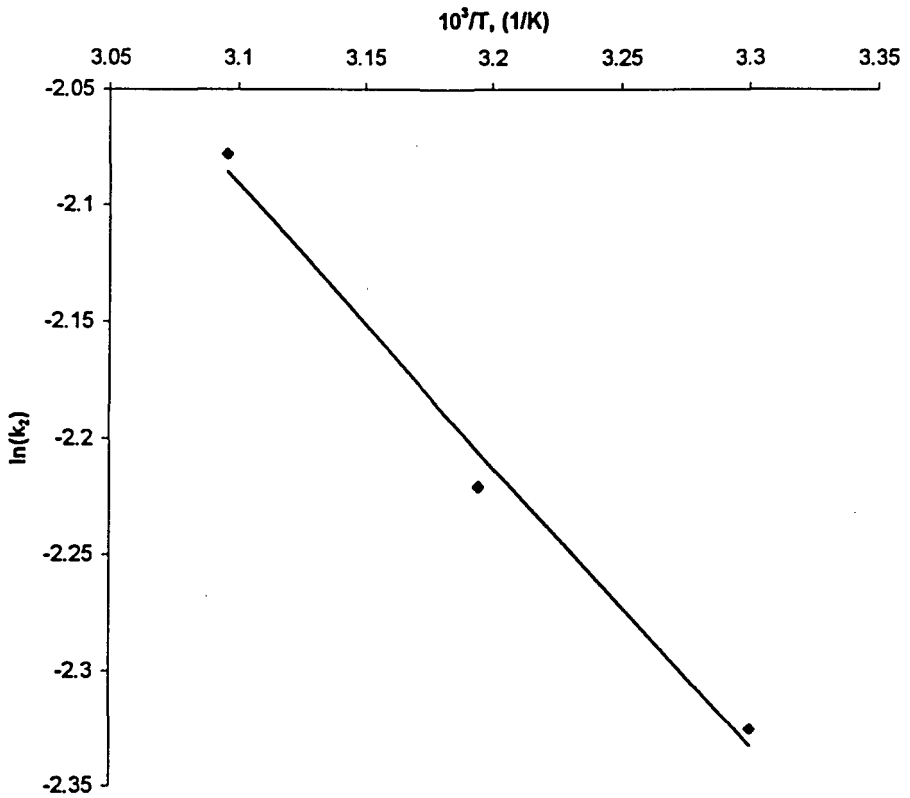


FIGURE 15  
Plot of  $\ln(k_2)$  Versus  $1/T$  for Omega Chrome Red ME.

TABLE 3  
Empirical Parameters for Predicted  $q_e$  and  $h$  from T

	$A_q$	$B_q$	$r^2$	$A_h$	$B_h$	$r^2$
PNP	$-6.18 \times 10^2$	4.01	0.962	$-2.50 \times 10^3$	9.07	0.980
OCL	$-5.84 \times 10^2$	3.21	0.990	$-2.54 \times 10^3$	7.33	1.00
OCRME	$1.37 \times 10^3$	-5.18	0.998	$1.53 \times 10^3$	-8.70	1.00

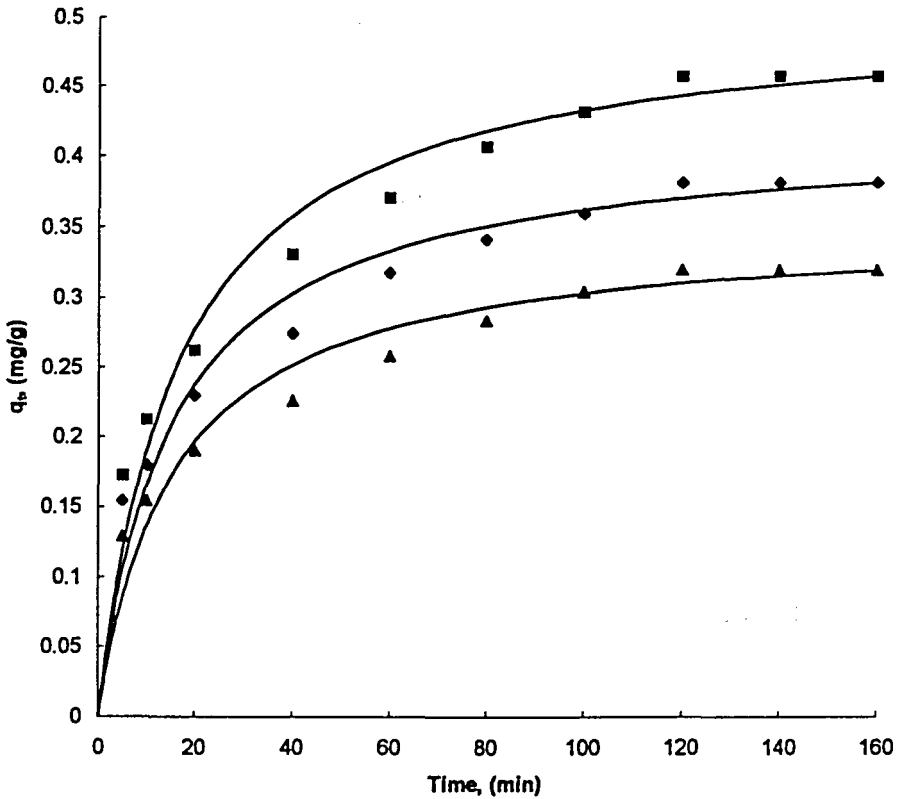


FIGURE 16

Effect of Particle Size of Omega Chrome Red ME. Symbols: Experimental Data ■ 53  $\mu\text{m}$ , ◆ 75  $\mu\text{m}$ , ▲ 125  $\mu\text{m}$ ; - Second Order Model.

for OCRME:

$$q_t = \frac{t}{\exp\left(8.70 - \frac{1.53 \times 10^3}{T}\right) + \left[\exp\left(5.18 - \frac{1.37 \times 10^3}{T}\right)\right] t} \quad (10)$$

These equations can then be used to derive the amount of dye sorbed at any given temperature and the reaction time.

#### Effect of Particle Size

Figure 16 shows a series of contact time curves with sorbent size from 53

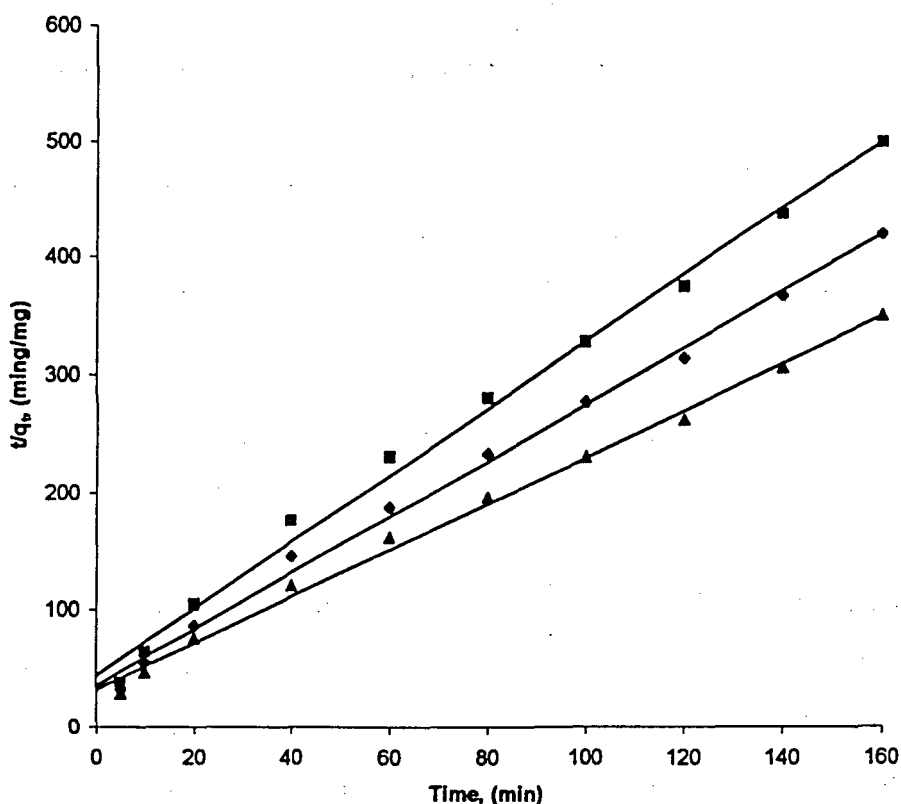


FIGURE 17

Pseudo-Second Order Sorption Kinetics of Omega Chrome Red ME on Fly Ash. Symbols: Experimental Data ■ 125  $\mu\text{m}$ , ◆ 75  $\mu\text{m}$ , ▲ 53  $\mu\text{m}$ ; - Second Order Model.

to 125  $\mu\text{m}$  of OCRME and Figure 17 shows the plot of  $t/q_t$  against time,  $t$ , based on the assumption of a pseudo-second order mechanism. The removal of OCRME increases from 64.4 to 92.4% with the decrease of the fly ash particle size from 53 to 125  $\mu\text{m}$ . This indicates that the smaller the sorbent particle size, then for a given mass fly ash, more surface area is made available and therefore the number of available system sites increases. The results are shown in Table 4. The correlation coefficients,  $r_2^2$ , and the pseudo-second order rate



**TABLE 4**  
**A Comparison of Rate Parameters of Particle Size for OCRME**

$d_p$	$r_2^2$	$q_e$	$k_2$	$h$	$r_1^2$	$k_1$	$r_i^2$	$k_i$
53	0.995	0.503	0.122	$3.10 \times 10^{-2}$	0.965	$1.37 \times 10^{-2}$	0.966	$2.86 \times 10^{-2}$
75	0.996	0.417	0.160	$2.78 \times 10^{-2}$	0.965	$1.40 \times 10^{-2}$	0.963	$2.30 \times 10^{-2}$
125	0.994	0.351	0.182	$2.24 \times 10^{-2}$	0.966	$1.39 \times 10^{-2}$	0.971	$1.93 \times 10^{-2}$

$d_p$ :  $\mu\text{m}$ ,  $q_e$ :  $\text{mg/g}$ ,  $k_2$ :  $\text{g/mgmin}$ ,  $h$ :  $\text{mg/gmin}$ ,  $k_1$ :  $1/\text{min}$ ,  $k_i$ :  $\text{mg/gmin}^{0.5}$

parameters,  $k_2$ , are shown and compared with  $r_1^2$  and  $k_1$  values for the pseudo-first-order model, as well as  $r_i^2$  and  $k_i$  values for the intraparticle diffusion based model. The data show a good correlation with the pseudo-second order equation and the regression coefficients for the linear plots were higher than 0.996 for all these studies. The correlation coefficients of the intraparticle diffusion model are given in Table 4 for the effect of contact time and particle size of OCRME and although they are all greater than 0.958 they are lower than the coefficients obtained for the second order kinetic model. Table 4 also indicated that the correlation coefficients of the pseudo-first order model are all greater than 0.957 they are lower than the coefficients obtained for the second order kinetic model. Again the equilibrium sorption capacity could not be obtained reasonably from the intercept of the equation (1) and again the linearity of the pseudo-first order plots are only valid for two hours. It suggests that the preferred sorption mechanism is pseudo-second order rather than a pseudo-first order model.

In Table 4 all correlation coefficients are extremely high. The sorption process may involve a chemical reaction process and demonstrates that the pseudo-second order rate constant,  $k$ , is a function of surface area of the sorbent. The initial sorption rates,  $h$ , are decreasing with increasing particle size. This would be expected since the amount of external surface area available for rapid reaction decreases with increasing particle size for constant sorbent mass.

### CONCLUSION

The kinetics of sorption of aromatic compounds, *p*-nitrophenol and *o*-cresol as well as a chrome dye, Omega Chrome Red ME (OCRME) on fly ash were studied and analysed by three mechanisms. The sorption of *o*-cresol (OCL) and *p*-nitrophenol (PNP) on fly ash are exothermic, activated processes and the best fit kinetic sorption model is the pseudo-second order model. However the sorption of Omega Chrome Red ME on fly ash appears to be an endothermic process and intraparticle diffusion and chemical reaction both seem relatively significant in the rate controlling step. The activation energy of sorption can be evaluated with the pseudo-second order rate constants for the sorption of PNP and OCL on fly ash.

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