COMPARISON STUDY BETWEEN DUBININ-RED USHKEVICH AND TEMKIN MODEL FOR ADSORPTION OF MERCURY ONTO ACTIVATED CARBON

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ABSTRACT:

Activated carbon has been used as an adsorbent in this work to remove mercury from aqueous solutions. The aim of the work is to test how best activated carbon can be used as an adsorbent for mercury. Equilibrium isotherms, both, Dubinin-Redushkevich, and Temkin have been test. The batch experiments were conducted at room temperature (30^oC) and at the normal pH (7.0±0.1) of the solution. HYBRID fraction error function analysis shows that the best-fit for the adsorption equilibrium data is represented by (D-R) model rather than Temkin model. Its found that the correction factor (R^2) for (D-R) is 0.9928 while for Temkin model is 0.942, also the HYBRID fractional error was conducted for the both models and (D-R) model give minimum value of (0.0128) while it was (0.129) for Temkin.

الخلاصة :

يهدف البحث الى اجراء المقارنة لفاعلية موديلين رياضيين هما موديل Dubinin-Redushkevich وموديل Temkin لوصف عملية امتزاز الزئبق ضمن المحلول المائي باستخدام الكاربون المنشط . وقد تم اجراء التجارب المتقطعة في درجة حرارة 30˚ وقيمة (pH=7) وقد وجد ان معامل التصحيح (R^2) للموديل الرياضي الاول يساوي (0.9928) بينما كانت القيمة للموديل الثاني تساوي (0.942) كذلك تم تطبيق معيار (HYBRID) الانحرافي للخطأ ووجد ان قيمته للموديل الاول يساوي (0.0128) بينما للموديل الثاني (0.129) .

KEYWORDS
Adsorption, Mercury, Wastewater treatment, Isotherms, Kinetics.

INTRODUCTION:

Mercury has been chosen in this work for experimentation. Among several methods for the removal of heavy metal from solutions (precipitation, evaporation, electroplating, ion exchange and membrane separation). Adsorption onto activated carbon proves to be an efficient and cost effective method. In the present study, adsorption of mercury on AC has been studied at the normal pH (7.0±0.1) of the solution and at room temperature (30^oC). Number of works on the removal of mercury using activated carbon had been reported(both Redad and Ruble),In addition to find the adsorption capacity of activated carbon for mercury,also to test the validity of batch experimental data to various two parameters adsorption isotherm models such as Dubinin-Redushkevich, and Temkin models.

Dubinin-Redushkevich (D-R) Model

This adsorption isotherm(Dubinin-Redushkevich) is given as:

$$q_e = q_m \exp(-Be^2) \qquad \ldots\ldots. (1)$$

Where q_m (mol/g) is the theoretical monolayer saturation capacity of the adsorbent and e (known as Polanyi potential) is given as:

$$e = RT\,In(1+\frac{1}{C_e}) \qquad \ldots\ldots\ldots (2)$$

The constant B (mol^2/J^2) given by the following equation, the mean free energy E (J/mol) of adsorption per molecule of adsorbate, when it is transferred to the surface of solid from infinity in the solution, is:

$$E = \frac{1}{\sqrt{2B}} \qquad \ldots\ldots. (3)$$

The linear from of D-R equation is:

$$In\ q_e = In\ q_m - Be^2 \qquad \ldots\ldots. (4)$$

Temkin Model:

The Temkin adsorption isotherm is expressed as:

$$q_e = \frac{RT}{b} In(K_T C_e) \qquad \ldots\ldots. (5)$$

The linearized form of the above equation is:

$$q_e = B_1\ In\ K_T - B_1\ In\ C_e \qquad \ldots\ldots. (6)$$

Where B_1=RT/b; R is the universal gas constant (8.314J/mol K) and T is the absolute temperature (K)(Temkin).

EXPERIMENTAL:

Materials and Methods

The chemical used were mercury (II) chloride (Merck), and activated carbon (Merck). Specifications of activated carbon are given in table 1. The surface area of AC used is 1250 m^2/g and the Hg(II) was determined by using spectrophotometer (HITACHI 2000).

Adsorption Experiments

100mL solutions of 50 mg/L Hg(II) concentration each were treated with 20, 40, 60, 80, 100, 120, 140, 160, and 180 mg of AC, respectively, and equilibrated for a period of 24h at room temperature and at a pH of 7.0±0.1 of the solution in an orbital flask shaker.

The solutions were then filtered and the residual Hg(II) concentrations determined spectrophotometrically.

Table 1: Specifications of activated carbon

Specifications	Value
Porosity	70-80%
Cation Exchange Capacity	0.71 meq/g
Surface Area	1250 m^2/g
Average Particle Size	250 μm
Particle Density	0.887 g/cm^3

RESULTS AND DISCUSSION

Experimental data (Table 2) on equilibrium studies for the adsorption of Hg(II) on AC were tested to fit the various two-parameter adsorption isotherm models.

Table 2: Batch experimental data for the Adsorption of Hg(II) on AC, at normal pH and at room temperature (30^{o}c)

Equilibrium Studies	
Activated Carbon	
q_e (mg/g)	C_e (mg/L)
57.33	32.8
46.10	22.4
39.78	14.2
33.17	10.2
28.33	7.5
24.50	5.9
21.67	4.5
18.60	3.5
15.87	2.4
12.20	1.3

Linearized forms of the (D-R) and Temkin adsorption isotherms, the values of parameters involved and the correction correlations are given in Table 3.

Table 3: Two-parameters adsorption isotherm models and parameter values of the isotherms for the adsorption of Hg(II) on activated carbon at normal pH of the solution and at room temperature (30^{o}C)

Model	Linearized Equation	Parameters values for the adsorption of HG(II)
Dubinin-Resushkevich (D-R)	$Inq_e=Inq_m-Be^2$	$B=4x10^{-9}$; $q_m=1.59x10^{-3}$; $E=11180$;$R^2=0.9928$
Temkin	$q_e=B_1InK_T+B_1InC_e$	$K_T=1.23$;$B_1=13.951$; $R^2=0.942$

A plot of q_e versus e^2 should yield straight line. This plot for the present experimental data is shown in Fig. 1. the fits are good in the present study ($R^2 = 0.9955$ for AC).

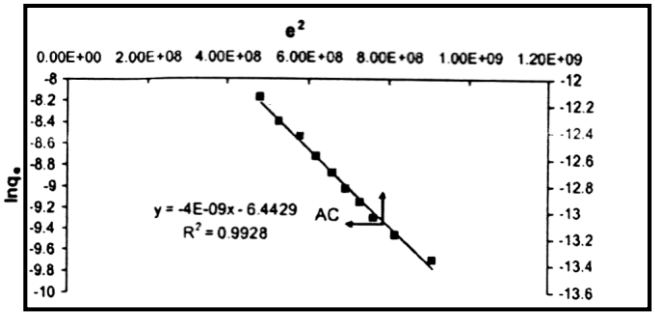

Fig (1): Dubinin-Redushkevich plots

Temkin isotherm takes in to account the adsorbing species-adsorbent interactions. A plot of q_e versus In C_e yields a straight line (Fig. 2) from which the isotherm constants B_1 and K_T (L/mg) can be determined, K_T is the equilibrium binding constant corresponding to the maximum binding energy and constant B_1 is related to the heat of adsorption.

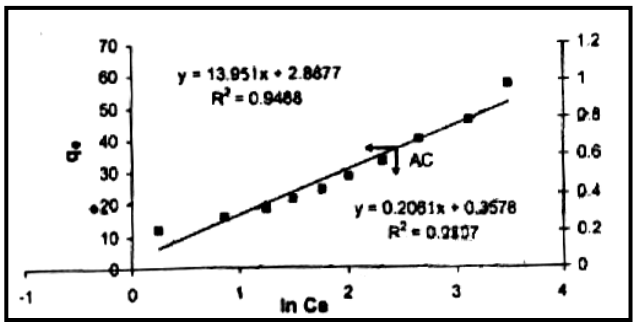

Fig (2): Temkin plots

BEST-FITTING ISOTHERM MODEL:

Both the isotherms studied in this work are in their linearized form. Due to the inherent bias resulting from linearization, to find of the best-fit isotherm model to the experimental equilibrium data, the hybrid fractional error function of non-linear regression is employed, as it compensates for low concentrations by balancing absolute deviation against fractional error and is more reliable than other error functions. The hybrid error is given as:

$$\text{HYBRID} = \frac{100}{N-p}\sum\left[\frac{q_e.\exp - q_e.\text{calc}}{q_e.\exp}\right]_i \quad \ldots. (7)$$

Where N is the number of data points and p is the number of parameters in the isotherm model. The hybrid error is lowest for (D-R) model for adsorption on AC (0.0128) and for Temkin model was (0.129) and hence the best-fit is the (D-R) adsorption isotherm.

CONCLUSIONS:

The present study shows that activated carbon, follows the adsorption isotherm models tested; Dubinin-Redushkevich, and Temkin. However, the best-fit isotherm is the (D-R) model isotherm, as determined by hybrid fractional error analysis, also it clear that the values of R^2 for the (D-R) model are better for the Temkin model.

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