EQUILIBRIUM AND KINETICS OF CADMIUM AND ZINC ADSORPTION ON ACTIVATED CARBON FROM PALM KERNEL SHELL

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EQUILIBRIUM AND KINETICS OF CADMIUM AND ZINC ADSORPTION ON ACTIVATED CARBON FROM PALM KERNEL SHELL

By

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October 2006

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A series of batch laboratory studies were conducted in order to investigate the suitability of palm kernel shell (PKS)-based activated carbon for the removal of cadmium (cadmium ions) and zinc (zinc ions) from their aqueous solutions. Single and binary adsorption isotherms and kinetics were investigated. All batch experiments were carried out at a constant temperature of 30±1°C using an incubator shaker that operated at 150 rpm. A concentration ratio of cadmium and zinc used in the adsorption of binary system is 1:1.

Batch equilibrium studies showed that adsorption of cadmium and zinc were highly pH dependent. Uptake of cadmium and zinc increased with pH with maximum removal observed at pH 7.0, and decreased thereafter with further increase in the initial pH. In a single component system, the adsorption capacity of cadmium was higher than zinc, whilst in a binary component system, the adsorption capacity of zinc was higher than cadmium.

The single component equilibrium data was analyzed using the Langmuir, Freundlich and Redlich–Peterson isotherms. Overall, the Redlich-Peterson isotherm showed the best fit for all adsorption under investigation in terms of correlation coefficient as well as error analysis. For all the systems studied, the analysis of isotherm shape factor showed that the adsorption was favorable.

Equilibrium isotherms for the binary adsorption of cadmium (II) and zinc (II) ions onto PKS-base activated carbon have been analyzed by using the ideal adsorbed solution (IAS) theory, extended Langmuir (EL), modified extended Langmuir (MEL), modified extended Freundlich (MEF) and modified extended Redlich-Peterson (MERP) models. The binary isotherm data could be described reasonably well by the modified extended Langmuir model.

The kinetics of single and binary systems describing the sorption of cadmium and zinc have been investigated. The rate models evaluated include the pseudo first order, the pseudo-second order and the intraparticle diffusion models. Kinetic data showed that the adsorption rates were a function of initial adsorbate concentration. For both single and binary systems, the pseudo-second order model correlate excellently the experimental data, suggesting that chemisorption processes could be the rate- limiting step.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai
memenuhi keperluan untuk ijazah Master Sains

KESEIMBANGAN DAN KINETIK BAGI PENJERAPAN KADMIUM DAN ZINK KE ATAS KARBON TERAKTIF DARIPADA TEMPURUNG KELAPA SAWIT

Oleh

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Oktober 2006

Pengerusi : Profesor Madya Thomas Choong Shean Yaw, Ph.D.

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Satu siri ujikaji telah dijalankan di makmal untuk mengkaji keberkesanan penggunaan karbon teraktif daripada tempurung kelapa sawit (PKS) untuk menjerap bahan logam kadmium (ion kadmium) dan zink (ion zink) daripada larutan berair. Penjerapan isoterma tunggal dan perduaan serta kinetik telah disiasat. Semua uji kaji dijalankan pada suhu tetap iaitu 30±1°C menggunakan penggoncang inkubator yang beroperasi pada kelajuan 150 rpm. Nisbah kepekatan cadmium dan zink yang telah digunakan pada penjerapan system perduaan adalah 1:1.

Penyelidikan keseimbangan kelompok telah menunjukkan bahawa penjerapan kadmium dan zink adalah sangat bergantung kepada pH. Pengambilan kadmium dan zink meningkat berdasarkan pH dan pemisahan maksimum didapati pada takat pH 7.0 dan seterusnya akan berkurangan dengan peningkatan pH. Di dalam sistem komponen tunggal, kapasiti penjerapan terhadap kadmium adalah lebih

tinggi daripada zink dan pada masa yang sama sistem komponen perduaan, kapasiti penjerapan terhadap zink lebih tinggi daripada kadmium.

Data keseimbangan pada komponen tunggal telah dikaji dengan menggunakan garis sesuhu (isoterma) Langmuir, Freundlich and Redlich–Peterson. Secara keseluruhannya, isoterma Redlich–Peterson menunjukkan padanan paling sesuai untuk kesemua penjerapan yang diselidiki, berdasarkan kepada pekali berkait dan juga ralat analisa. Untuk keseluruhan sistem yang dikaji, analisa terhadap faktor pembentukan garis sesuhu telah menunjukkan bahawa penjerapan telah terhasil.

Keseimbamgan isoterma untuk penjerapan perduaan bagi ion kadmium II dan zink II kepada karbon teraktiv telah dikaji dengan menggunakan teori unggul jerapan larutan berair (IAS), model lanjutan Langmuir (EL) model lanjutan Langmuir yang telah diubah (MEL), model lanjutan Freundlich yang telah diubah (MEF) dan model lanjutan Redlich-Peterson yang telah diubah (MERP). Data perduaan isoterma boleh digambarkan dengan baik oleh model lanjutan Langmuir yang telah diubah (MEL).

Oleh kerana adanya persaingan penjerapan perduaan, teori unggul jerapan larutan berair (IAS) dan model lanjutan Langmuir (EL) tidak boleh menentukan komponen isoterma perduaan. Oleh itu tiga perkaitan model seperti model lanjutan Langmuir, model lanjutan Freundlich dan model lanjutan Redlich-Peterson yang telah diubah digunakan untuk pemadanan data sistem keseimbangan perduaan. Data isoterma perduaan boleh diterangkan dengan jelas oleh model lanjutan Langmuir yang telah diubah.

Model kinetik untuk sistem tunggal dan perduaan menerangkan bahawa penjerapan kadmium dan zink telah pun disiasat. Model kadar yang telah diselidiki termasuk arahan pseudo pertama, arahan pseudo kedua dan model resapan intrapartikel. Data kinetik menunjukkan bahawa kadar penjerapan adalah bergantung kepada kepekatan zat terjerap awal. Bagi kedua-dua sistem iaitu tunggal dan perduaan, model arahan pseudo kedua menunjukkan kaitan yang tinggi terhadap data eksperimen, dan ini dapat diusulkan bahawa proses penjerapan kimia boleh dijadikan sebagai langkah kadar terhad.

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I certify that an Examination Committee has met on 03rd October 2006 to conduct the final examination of Muhammad on his Master of Science thesis entitled "Equilibrium and Kinetics of Cadmium and Zinc Adsorption on Activated Carbon from Palm Kernel Shell" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

MUHAMMAD

Date: 19 December 2006

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LIST OF ABBREVIATIONS/NOTATIONS/SYMBOLS

a_F	*Freundlich constant*	*L.mg^{-1}*
a_L	*Langmuir constants (adsorption intensity)*	*L.mg^{-1}*
a_R	*Redlich-Peterson constants*	*L.mg^{-1}*
b_{ij}	*Correlation constants in empirical Freundlich*	
C_e	*Concentration of solute in the solution at equilibrium*	*mg.L^{-1}*
$C_{e,i}$	Equilibrium concentration of the component *i* in the multi-component solution	*mg.L^{-1}*
C_t	*Concentration of the solution at time t*	*mg.L^{-1}*
D_{meso}	*Average mesopore diameter*	*Å*
D_{micro}	*Average micropore diameter*	*Å*
k_1	*Equilibrium rate constant of pseudo first-order sorption*	*min^{-1}*

k_2	*Equilibrium rate constant of pseudo second-order sorption*	*g* $mg^{-1}.min^{-1}$
k_{id}	*Intra-particle diffusion rate constant*	*Mg* $g^{-1}min^{-0.5}$
K_L	*Langmuir constant (adsorption capacity)*	$L.g^{-1}$
K_R	*Redlich-Peterson constant (adsorption capacity)*	$L.g^{-1}$
n	*Freundlich exponent (Surface heterogeneity)*	$L.mg^{-1}$
N	Number of points in data set	
R_L	*Separation factor*	
t	*Time*	*minute*
q_m	*Monolayer capacity of the Langmuir isotherm*	$mg.g^{-1}$
q_e	*Solid phase concentration at equilibrium*	$mg.g^{-1}$
q_t	*Solid phase concentration at time t*	$mg.g^{-1}$

X	*Mass fractions*	
S_{BET}	*BET specific surface of activated carbon*	$m^2.g^{-1}$
V	*Volume of solution*	*mL*
V_{meso}	*Mesopore volume*	$cm^3.g^{-1}$
V_{micro}	*Micropore volume*	$cm^3.g^{-1}$
V_{total}	*Total pore volume*	$cm^3.g^{-1}$
AC	*Activated carbon*	
IUPA	*International Union of Pure and Applied*	
C	*Chemistry*	
PKS	*Palm Kernel Shell*	

Greek notation

β	*Heterogenity factor*
β_j^0	*Heterogenity factor for single-component*

	Redlich-Peterson constants in solute i	
η_i	Redlich-Peterson correction coefficient of the *i* component	
$\eta_{L,i}$	Langmuir correction coefficient of the *i* component	
λ_{max}	*Maximum wavelength*	*nm*
ψ	*Spreading pressure*	$N.m^{-1}$

Superscripts

mix	Mixture
0	Single-solute data
P	*Predict*

Subscripts

Cal	*Calculated*
exp	*Experimental*
i, j	*Component number index*
O	Initial
T	Total value for the system