UNIVERSITI PUTRA MALAYSIA

EQUILIBRIUM STUDIES AND DYNAMIC BEHAVIOUR OF CADMIUM AND COPPER ADSORPTION ONTO PALM OIL FLY ASH

ABDUL SHUKOR BIN ABDUL AZIZ

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MASTER OF SCIENCE
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By

ABDUL SHUKOR BIN ABDUL AZIZ

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the degree of Master of Science

May 2014

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DEDICATION

TO MY BELOVED MOTHER
MARIAM MOHAMED

&

IN LOVING MEMORY OF MY LATE FATHER
HAJI ABDUL AZIZ HAJI SAMSUDDIN

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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By

ABDUL SHUKOR BIN ABDUL AZIZ

May 2014

Chair : Assoc. Prof. Latifah Abd Manaf, PhD
Faculty : Environmental Studies

Over the past century, human activities have led to severe environmental degradation especially heavy metals contamination. The role of adsorption using agricultural by-products has been critically investigated in order to develop cheaper and more effective natural adsorbents for the removal of heavy metals from wastewater. Therefore, in this present study, the adsorption performance and characteristics of palm oil fly ash (POFA) were investigated for the removal of Cd(II) and Cu(II) from aqueous solution. The studies were conducted using batch and fixed-bed column experiments and the characterization of the POFA was determined through BET, SEM/EDX and FT−IR analysis. A series of batch adsorption studies were conducted with the effects of relevant parameters such as contact time, initial solution pH, adsorbent dosage and initial metal ions concentration. Fundamental batch study indicated that 80% of Cd(II) and Cu(II) were removed in the first 30 minutes of agitation. Meanwhile, both Cd(II) and Cu(II) uptake mechanism were particularly pH- and concentration-dependant, favoring a pH value of 7 and 6 respectively. The experimental data were analyzed using the Langmuir, Freundlich and Temkin isotherm models. The adsorption behavior of Cd(II) and Cu(II) fitted well to the Langmuir isotherm, with a maximum monolayer adsorption capacity of 15.82 and 17 mg/g respectively. The applicability of the Langmuir isotherm suggested the formation of monolayer coverage of metal ions onto equivalent sites of the adsorbent. Kinetics experimental data followed the trend of pseudo second-order kinetics, which was consistent with chemisorptions with intraparticle diffusion involved as one of the rate determining step. The performance of continuous fixed-bed columns study for the adsorption of Cd(II) and Cu(II) onto POFA were described through the concept of breakthrough curve under relevant operating conditions such as adsorbent bed depths and influent metal concentrations. Results showed that the breakthrough time increases with increasing bed depth, and decreases as the influent metal concentration increases. The Cd(II) and Cu(II) uptake mechanism were particularly bed depth- and concentration-dependant, favouring higher bed depth and lower influent metal concentration. The maximum uptakes of Cd(II) and Cu(II) in a fixed-bed column at bed depth of 2 cm and influent metal concentration of 20 mg/L were found to be 34.91 and 21.93 mg/g, respectively. The column experimental data

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were analyzed using the bed depth service time (BDST), Thomas, and Yoon–Nelson models. The Thomas and Yoon–Nelson models were successfully applied in describing the dynamic behavior of the adsorption process, indicating that both models were very compatible for the POFA column design over a range of feasible bed depths and concentrations. However, the initial region of the breakthrough curve for Cd(II) adsorption was better described using the BDST model. Conclusively, this study indicates that POFA could be used successfully as a natural low-cost adsorbent for the removal of Cd(II) and Cu(II) from aqueous solution.

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

KAJIAN KESEIMBANGAN DAN PERLAKUAN DINAMIK BAGI PENJERAPAN KADMIUM DAN KUPRUM KE ATAS ABU TERBANG KELAPA SAWIT

Oleh

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Sejak abad yang lalu, aktiviti manusia telah membawa kepada kemusnahan alam sekitar yang teruk terutamanya berpunca daripada pencemaran logam berat. Peranan penjerapan menggunakan bahan buangan pertanian telah diselidik secara kritikal dalam usaha untuk membangunkan penjerap semula jadi yang lebih murah dan berkesan bagi penyingkiran logam berat daripada air sisa. Oleh itu, di dalam kajian ini, prestasi penjerapan dan ciri-ciri abu terbang kelapa sawit (POFA) telah diselidik untuk penyingkiran Cd(II) dan Cu(II) daripada larutan akueus. Kajian ini telah dijalankan menggunakan kajian kelompok dan kolum media tetap dan pencirian POFA telah ditentukan melalui analisis BET, SEM/EDX dan FT−IR. Satu siri kajian penjerapan kelompok telah dijalankan dengan kesan parameter yang relevan seperti masa sentuhan, pH awal larutan, dos bahan penjerap dan kepekatan awal ion logam. Kajian kelompok fundamental menunjukkan bahawa 80% daripada Cd(II) dan Cu(II) telah disingkirkan dalam masa 30 minit pertama pergolakan. Sementara itu, kedua-dua mekanisme penyerapan Cd(II) dan Cu(II) adalah bergantung kepada pH dan kepekatan, di mana masing-masing memihak pada nilai pH 7 dan 6. Data eksperimen telah dianalisis dengan menggunakan model isoterma Langmuir, Freundlich dan Temkin. Perlakuan penjerapan Cd(II) dan Cu(II) mematuhi isoterma Langmuir, dengan kapasiti maksimum penjerapan lapisan mono masing-masing pada 15.82 dan 17 mg/g. Kesesuaian isoterma Langmuir mencadangkan bahawa pembentukan lapisan mono ion logam meliputi ruangan yang sama rata pada bahan penjerap. Data eksperimen kinetik mematuhi trend kinetik pseudo tertib-kedua, yang konsisten dengan penjerapan kimia yang melibatkan difusi intrapartikal sebagai salah satu daripada langkah kadar penentu. Prestasi kajian kolum media tetap secara berterusan bagi penjerapan Cd(II) dan Cu(II) ke atas POFA dihuraikan menerusi konsep keluk kejayaan di bawah keadaan operasi yang relevan seperti kedalaman media penjerap dan kepekatan logam influen. Hasil kajian menunjukkan bahawa masa kejayaan meningkat dengan peningkatan kedalaman media dan bekurangan apabila kepekatan logam influen meningkat. Mekanisme penyerapan Cd(II) dan Cu(II) adalah bergantung khususnya pada kedalaman media dan kepekatan, yang memihak kepada kedalaman media yang lebih tinggi dan kepekatan logam influen yang rendah.

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Penjerapan maksimum Cd(II) dan Cu(II) menggunakan kolum media tetap pada kedalaman media 2 cm dan kepekatan logam influen sebanyak 20 mg/L masing-masing didapati pada 34.91 dan 21.93 mg/g. Data eksperimen kolum telah dianalisis dengan menggunakan model masa perkhidmatan kedalaman media (BDST), Thomas, dan Yoon−Nelson. Model Thomas dan Yoon−Nelson telah berjaya digunapakai dalam menerangkan perlakuan dinamik proses penjerapan, menunjukkan bahawa kedua-dua model tersebut adalah sangat bersesuaian untuk reka bentuk kolum POFA dalam julat kedalaman media dan kepekatan yang sesuai. Walaubagaimanapun, bahagian awal keluk kejayaan bagi penjerapan Cd(II) adalah lebih sesuai diterangkan menggunakan model BDST. Kesimpulan yang dapat dibuat, kajian ini menunjukkan bahawa POFA boleh digunakan dengan jayanya sebagai penjerap semula jadi berkos rendah untuk penyingkiran Cd(II) dan Cu(II) daripada larutan akueus.

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I certify that a Thesis Examination Committee has met on 12 May 2014 to conduct the final examination of Abdul Shukor bin Abdul Aziz on his thesis entitled "Equilibrium Studies and Dynamic Behaviour of Cadmium and Copper Adsorption onto Palm Oil Fly Ash" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the University Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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