UNIVERSITI PUTRA MALAYSIA

UTILIZATION OF STEEL INDUSTRY SLAG FOR REMOVAL OF COPPER AND MANGANESE

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UTILIZATION OF STEEL INDUSTRY SLAG FOR REMOVAL OF COPPER AND MANGANESE

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

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Abstract of thesis presented to the Senate of University Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy.

UTILIZATION OF STEEL INDUSTRY SLAG FOR REMOVAL OF COPPER AND MANGANESE

By

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August 2011

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Faculty : Faculty of Engineering

Steel making slag from Electric Arc Furnace (EAF) is a major abundant by-product in Malaysia steel industry. It has potential to be used as low cost adsorbent for heavy metal removal from waste water. The aim of this study is to develop an innovative approach by using this EAF slag (EAFS) for heavy metals absorption particular manganese and copper in steel industry waste water. The removal characteristics and behavior of manganese and copper were investigated in term of adsorption kinetics and isotherm as well as the adsorption capacity in batch and fixed bed column system. In addition, the effects of the contact time, pH, temperature, particle size were determined in batch process and the effects of the bed depth and flow rate were examined in the fixed bed column system. Furthermore, the real waste water from steel making process was also carried out as case study in order to determine the practical aspect of the EAFS performance.

It is found that the EAFS adsorption kinetics can be described well by the Pseudo-2nd order kinetic model with fairly high correlation coefficients. The adsorption

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process obeyed the Langmuir isotherm model and the maximum uptake of the manganese and copper from the solution are 2.30 mg/g and 2.69 mg/g respectively. In binary adsorption, it can be seen that the amount of adsorption for both the metals are less than in single system. Thus, the difference of adsorption capacity showed that there was a competitive adsorption of the metal ion on the surface of EAFS.

The optimum pH and temperature was observed to be at pH 8 and 28^{o}C respectively for the maximum removal of both the manganese and copper. The equilibrium time was determined at 5 hours and 3 hours for manganese and copper respectively and it is noticed that both the metals adsorption capacity increase as the particle mean size of the EAFS decrease from 4mm to 1mm. The bed depth service time (BDST) model fitted well with the experimental data where the service time increased accordingly when the bed depth is increased. Thomas model also described well the adsorption behavior of the effect of flow rate on adsorption capacity and breakthrough curves. It is observed that the pH of the solution will be slightly increased from 7 to 8 due to the formation of calcium hydroxide (CaOH) from calcium oxide (CaO) present in the EAFS. From the study, it was concluded that the EAFS can be an efficient low cost adsorbent to remove heavy metals particularly manganese and copper from steel industry waste water.

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Abstrak tesis ini dikemukakan kepada Senat Universiti Putra Malaysia untuk memenuhi keperluan ijazah Doktor Falsafah.

PENGGUNAAN SLAG INDUSTRI BESI UNTUK PENYIKIRAN KUPRUM DAN MANGAN

Oleh

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Ogos 2011

Penyelia : Profesor Luqman Chuah Abdullah, PhD

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Penghasilan slag daripada Elektrik Arka Perapian (EAP) merupakan satu bahan sampingan utama yang banyak bagi industri pembuatan besi keluli di Malaysia. Ia mempunyai potensi untuk digunakan sebagai penjerap yang murah untuk penyikiran logam berat daripada air sisa. Tujuan kajian ini adalah untuk menghasilkan satu kaedah inovasi dengan menggunakan EAP slag (EAPS) untuk penjerapan logam berat terutamanya mangan dan kuprum dalam air sisa industri besi keluli. Kajian ciri-ciri dan tingkah laku penyikiran mangan dan kuprum dilakukan melalui penjerapan kinetic dan isoterma serta keupayaan jerapan secara sekumpul dan sistem kolum lapisan tetap. Beberapa parameter seperti masa kontak, pH, suhu, saiz zarah yang mempengaruhi process jerapan ditentukan manakala kesan parameter kedalaman lapisan dan laju aliran diperiksa dalam sistem kolum lapisan tetap. Air sisa sebenar daripada proses pembuatan besi juga telah dijalankan sebagai kajian kes untuk menentukan prestasi penyikiran oleh EAPS secara praktikal aspek.

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Didapati bahawa, kinetic penjerapan bagi EAPS boleh dijelaskan dengan baik berdasarkan model pseudo urutan-kedua dengan pekali korelasi yang cukup tinggi. Proses penjerapan tersebut adalah menepati model Langmuir isoterma di mana penyerapan maksimum bagi mangan serta kuprum dari larutan oleh EAPS adalah 2.30 mg/g dan 2.69 mg/g masing-masing. Dalam penjerapan campuran, ia dapat diperhatikan bahawa jumlah jerapan bagi kedua-dua logam adalah kurang berbanding dengan dalam sistem tunggal. Dengan demikian, kapasiti penjerapan yang berbeza bagi logam berat menunjukkan terdapat kompetitif jerapan pada permukaan EAPS.

pH 8 dan suhu 28^{o}C adalah diperhatikan optimum untuk mendapat penyingkiran yang maksimum bagi kedua-dua logam mangan dan kuprum. Masa keseimbangan bagi mangan ditentukan pada 5 jam manakala kuprum adalah pada 3 jam. Ini dapat dilihat bahawa kapasiti jerapan bagi mangan dan kuprum meningkat apabila purata saiz zarah bagi EAPS yang digunakan semakin kecil dari 4mm hingga 1 mm. Model servis masa kedalaman lapisan (BDST) menepati dengn baik data eksperimen apabila masa servis meningkat dengan peningkatan kedalaman lapisan. Model Thomas juga menjelaskan dengan baik parameter jerapan untuk menentukan pengaruh laju aliran ke atas keupayaan jerapan dan lengkung terobosan. Di samping itu, pH selepas EAPS kolum diperhatikan mengalami sedikit kenaikan dari 7 ke 8 yang disebabkan oleh pembentukan kalsium hidroksida (CaOH) daripada kalsium oksida (CaO). Daripada pengajian ini, ia dapat diputuskan bahawa EAPS boleh dijadikan sebagai penyerap yang murah dan berkesan untuk menyikirkan logam berat terutamanya mangan dan kuprum daripada air sisa industri besi keluli.

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I certify that a Thesis Examination Committee has met on 16th August 2011 to conduct the final examination of Beh Chin Lai on his Doctor of Philosophy thesis entitled "Utilization of Steel Industry Slag for Removal of Copper and Manganese" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The committee recommends that the student be awarded the Doctor of Philosophy.

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at University Putra Malaysia or at any other institution.

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Date : 16 August 2011

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