PENJERAP KOMPOSIT “LIGNOSELULOSA-KARBON TERAKTIF (BUAH SEMARAK API)” DAN KAOLIN DALAM RAWATAN AIR SISA GETAH ASLI MENTAH

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Tesis ini dikemukakan sebagai
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ABSTRAK

Pembangunan industri getah asli mentah menyumbang kepada krisis alam sekitar akibat daripada penjanaan air sisa yang berlebihan. Air sisa getah asli mentah ini mengandungi BOD, COD, ammoniakal nitrogen dan pepejal terampai yang tinggi. Dengan itu, teknologi baharu penjerap komposit dalam rawatan air sisa berpotensi menyingkirkan bahan pencemar. Penjerap komposit yang dihasikkan ini dari buah semarak api (lignoselulosa dan karbon teraktif) dan kaolin. Ujikaji kelompok dan turus lapisan tetap digunakan dan nisbah optimum komposit ditentukan menggunakan kaedah reka bentuk campuran D-optimal. Pencirian penjerap komposit dibuat terhadap luas permukaan BET, Mikroskop Imbasan Elektron Analisis Elemen-Sinar-X Sebaran Tenaga (SEM-EDX), Potensi Zeta dan Spektroskopi Inframerah Transformasi Fourier (FTIR). Dua model isoterma penjerapan Langmuir dan Freundlich digunakan untuk menyelidik isoterma penjerapan. Model kinetik Pseudo-tertib pertama, Pseudo-tertib kedua, Elovich dan Intra-partikel untuk meneliti sifat kinetik. Penjanaan semula bahan penjerap komposit sehingga lima pusingan penjerapan atau nyahjerapan juga disiasat. Keputusan mendapati nisbah komposisi optimum komposit ialah 0.4 g lignoselulosa, 0.8 g karbon teraktif dan 0.8 g kaolin. Keadaan optimum penjerapan COD, NH_3-N dan warna bagi penjerap komposit pada dos 4 g bahan penjerap, pH 8, halaju goncangan 150 PPM dan 120 minit masa sentuhan dengan penyingkiran maksimum masing-masing ialah 81.7%, 80.2% dan 93.3%. Luas permukaan (BET) bahan penjerap komposit ialah 63.60 m^2/g dan nilai negatif potensi zeta menunjukkan potensi dalam proses penjerapan. Analisis pencirian FTIR dan SEM-EDX mendedahkan penukaran ion sebagai mekanisma utama sebelum dan selepas penjerapan. Model isoterma penjerapan menunjukkan bahawa data isoterma penjerapan komposit ini sesuai dengan isoterma Langmuir dan kinetic penjerapan menunjukkan pematuhan yang baik untuk model Pseudo-tertib kedua. Turus lapisan tetap dianalisa dan keputusan menunjukkan bahawa pada kadar aliran rendah 2 mL/min mematuhi model Thomas dan Yoon-Nelson berbanding dengan model Adam-Bohart. Analisis penjerapan atau nyahjerapan telah mencapai tiga kitaran kebolehgunaan penjerap komposit. Kesimpulannya, kajian ini telah membuktikan bahwa penjerap komposit berpotensi dalam menyingkirkan COD, NH_3-N dan warna daripada air sisa getah asli.

ABSTRACT

The development of the natural rubber industry contributed to the environmental crisis due to the excessive wastewater generation. This raw natural rubber wastewater contains high levels of BOD, COD, ammoniacal nitrogen and suspended solids. In the response to the problems, new technology via composite adsorbents potentially removes contaminants in wastewater treatment. These composite adsorbent are made from Delonix Regia Pod (lignocellulose and activated carbon) and kaolin. Batch and fixed- bed adsorption techniques were used and the optimum ratio of compositeswas determined using the D-optimal mixing design method. Composite absorption characterization was performed using Brunauer-Emmett-Teller (BET), Scanning Electron Microscopy-Energy Dispersive X-Ray (SEM-EDX), Zeta Potential and Fourier Transform Infrared Spectroscopy (FTIR). Two versions of Langmuir and Freundlich adsorption isotherm were usedto analyze the adsorption isotherm. The Pseudo first order, Pseudo second order, Elovich and Intra-particles for the study of kinetic properties. Regeneration ofcomposite adsorbent materials up to five rounds of adsorption or desalination has alsobeen investigated. Results found that the optimal composition ratio was 0.4 g lignocellulose, 0.8 g activated carbon and 0.8 g kaolin. The optimum conditions of COD adsorption, NH_3-N, and colour of the composite adsorbent at a dose of 4 g of adsorbent material, pH 8, 150 rpm shaking velocity and 120 min contact time with maximum removal were 81.7%, 80.2%, and 93.3% respectively. The surface area ofthe BET composite adsorbent material is 63.60 m^2/g and the negative potential valueof zeta shows the potential for adsorption. FTIR and SEM-EDX characterization study showed the conversion of the ion as the main mechanism before and after adsorption. The adsorption isotherm model shows that the composite adsorption isotherm data corresponds to the Langmuir isotherm and the adsorption kinetics show strong compliance with the Pseudo second order model. The adsorption potential of the fixedbed column was analyzed and the results showed that the Thomas and Yoon-Nelson models met at a low flow rate of 2 mL/min compared with the Adam-Bohart model. The adsorption study was performed in three cycles of the usability of the composite adsorbent. In conclusion, this study showed that composite adsorbents have the ability to extract COD, NH_3-N, and colour from natural rubber wastewater.

KANDUNGAN

SENARAI JADUAL

SENARAI RAJAH

SENARAI SIMBOL

C_b	-	Kepekatan efluen atau kepekatan bolos	mg/L
C_e	-	Kepekatan pada keseimbangan	mg/L
C_L	-	Had kepekatan	mg/L
C_o	-	Kepekatan awal	mg/L
C_t	-	Kepekatan bolos pada masa *t*	mg/L
H	-	Ketinggian bahan penjerap penjerap dalam turus	mg/L
k_1	-	Pemalar kadar pseudo tertib pertama	cm atau m
k_2	-	Pemalar kadar pseudo tertib kedua	(min^{-1})
k_{AB}	-	Pemalar Adams Bohart	(g/mg min)
K_F	-	Pemalar Freundlich	(L/mg-min)
k_{TH}	-	Pemalar Thomas	$mgg^{-1}(gm^{-3})^n$
k_{YN}	-	Pemalar Yoon-Nelson	(mL/min-mg)
k_i	-	Pemalar kadar pembauran intra-partikel	(min^{-1})
K_L	-	Pemalar Langmuir	$(mg/g\ min^{0.5})$
n	-	Pekali dalam persamaan Freundlich	m^3g^{-1}
N_o	-	Kapasiti penjerapan atau kapasiti bolos	-
Q	-	Kadar aliran volumetrik	mg/L
q_e	-	Amaun penjerapan pada keseimbangan	mL/min
q_m	-	Amaun penjerapan maksimum	mg/g
q_t	-	Amaun penjerapan pada masa *t*	mg/g
t_b	-	Masa bolos	mg/min
t_e	-	Masa tepu	minit
V_e	-	Isipadu turus kosong	minit
V_0	-	Halaju linear	cm^3 atau m^3
X	-	Jisim penjerap yang digunakan	cm/min
Z	-	Kedalaman lapisan katil turus	cm atau m

$\tau_{0.50}$	-	Masa bolos pada C_t/C_o = 0.50	minit
Ɵ	-	Sudut sentuhan	darjah (°)

SENARAI SINGKATAN

AC	-	*Activated Carbon*
APHA	-	*American Public Health Association*
ASTM	-	*American Society for Testing and Materials*
ATR	-	*Attenuated Total Reflection*
AWWA	-	*American Water Works Association*
BET	-	*Brunauer, Emmet, Teller*
BK	-	Batu Kapur
BOD	-	Permintaan Oksigen Biokimia
BS	-	*British Standards*
CCD	-	*Charge-Coupled Device*
COD	-	Permintaan Oksigen Kimia
EBCT	-	*Empty Bed Contact Time*
FA	-	Asid Fulvik
Fe	-	Besi
FKAAS	-	Fakulti Kejuruteraan Awam dan Alam Sekitar
FTIR	-	Spektroskopi Inframerah Transformasi Fourier
GAC	-	*Granular Activated Carbon*
HA	-	Asid Humik
HCl	-	Asid Hidroklorik
JAS	-	Jabatan Alam Sekitar
KPK	-	Kapasiti Pertukaran Kation
KT	-	Karbon Teraktif
LOI	-	*Loss of Ignition*
MPRC	-	Pusat Penyelidikan Pencemar Mikro
MSW	-	*Municipal Solid Waste*
MTZ	-	*Mass Transfer Zone*

NaCl	-	Natrium Klorida
NaOH	-	Natrium Hidroksida
NH_3-N	-	Ammoniacal Nitrogen
PAC	-	*Powdered Activated Carbon*
pH_{ZPC}	-	pH Cas Titik Sifar
Pt.Co	-	*Platinum Cobalt*
RBC	-	Penyentuh Biologi Berputar
PPM	-	Pusingan Per Minit
SEM-EDX	-	Mikroskop Imbasan Elektron Analisis Elemen-Sinar-X Sebaran Tenaga
SS	-	Pepejal Terampai
UTHM	-	Universiti Tun Hussein Onn Malaysia
VFA	-	Asid Lemak Meruap
WCAT	-	*Water Contact Angle Test*
WDPT	-	*Water Drop Penetration Test*
WEF	-	*Water Environment Federation*
XRF	-	Analisis Pendarkilau Sinar-X

SENARAI LAMPIRAN

BAB 1

PENDAHULUAN

1.1 Pengenalan

Pengeluaran getah asli di seluruh dunia pada tahun 2020 berjumlah hampir 13 juta tan metrik berbanding tahun 2000 sebanyak 6.8 juta tan metrik getah asli. Pengeluar utama getah asli di dunia terdiri dari negara-negara Asia Tenggara. Thailand mengeluarkan 4.37 juta tan metrik getah asli pada tahun 2020, menjadikannya pengeluar utama getah asli terbesar di seluruh dunia. Ini diikuti oleh Indonesia yang menghasilkan 3.04 juta tan metrik. Sementara Malaysia, Vietnam, dan Filipina masing-masing menghasilkan sekitar 9.01%, 6.18%, dan 3.42% pengeluaran dunia (Oktora & Firdani 2019). Penggunaan terbesar getah asli dunia setakat ini ialah China menggunakan 5.4 juta tan metrik berbanding Thailand dan Indonesia kurang daripada satu juta tan metrik getah asli pada tahun 2020.

Getah asli berbentuk cecair putih yang dipanggil 'Latex' yang diperoleh daripada pokok getah Hevea Brasiliensis (Guerra *et al.*, 2021). Terdapat dua jenis proses dalam pemprosesan getah asli mentah iaitu pengeluaran lateks getah asli pekat (NRL) dan getah standard Malaysia (Ibrahim *et al.*, 2021). Walau bagaimanapun, pemprosesan getah asli mentah sentiasa membawa kepada penjanaan sejumlah besar air sisa tercemar (Chaijak & Sato 2021; Mokhtar *et al.*, 2015).

Air sisa getah asli mentah terdiri daripada campuran kompleks bahan organik yang tinggi seperti nutrien, pepejal terampai, nitrogen dan lain-lain. Secara umumnya, air sisa getah asli mentah ini mempunyai kepekatan permintaan oksigen biokimia (BOD), permintaan oksigen kimia (COD), ammoniakal nitrogen (NH_3-N), Nitrat, Fosforus dan jumlah pepejal terampai (SS) yang tinggi (Ilias *et al.*, 2021; Rosman *et al.*, 2014). Ciri-ciri air sisa getah asli mempunyai nilai pH diantara 3.6 hingga 8.3; pepejal terampai (SS), 200 hingga 700 mg/L; permintaan oksigen biokimia (BOD5), 700 hingga 1500 mg/L; permintaan oksigen kimia (COD), 3500 hingga 14000 mg/L; jumlah nitrogen (TN), 200 hingga 1800 mg/L dan sulfat, 500 hingga 2000 mg/L (Mokhtar et al., 2015).

Kawalan rawatan air sisa getah asli mentah perlu dilakukan bagi mengawal pelepasannya kepada alam sekitar. Peraturan alam sekitar yang dikuatkuasakan di Malaysia bagi mengawal loji rawatan air sisa getah asli mentah mesti mematuhi Peraturan-Peraturan Kualiti Alam Sekeliling (Getah Asli Mentah) 1978. Parameter piawai ini terdiri daripada suhu, pH, BOD, COD, NH_3-N dan SS.

Pelbagai pendekatan rawatan dalam merawat air sisa getah asli mentah seperti rawatan fizikal, kimia, biologi atau gabungan. Kaedah rawatan biologi seperti kolam fakultatif, aerobik dan anaerobik (Gaelen *at al.*, 2020) digunakan secara meluas untuk rawatan air sisa getah asli mentah seperti Malaysia, Thailand, Sri Lanka dan lain-lain. Walau bagaimanapun, sistem yang sedia ada ini tidak cekap untuk penyingkiran bahan organik dan pencemar mikro dalam air sisa getah asli mentah (Ashok *et al.*, 2015). Selain itu, sistem ini memerlukan ruang yang besar, tempoh rawatan efluen yang lebih lama, masalah bau, operasi dan kos penyelenggaraan yang tinggi. Keadaan ini membawa kepada ketidakpatuhan terhadap had pelepasan undang-undang (Rosman *et al.*, 2014).

Kaedah rawatan baharu air sisa getah asli mentah seperti kaedah penjerapan dilihat mempunyai keupayaan serapan yang baik (Daud *et al.*, 2018) dan mempunyai ciri pengoperasian dan rekabentuk yang mudah (Bhatnagar *et al.*, 2015) serta mampu untuk menyingkirkan bahan pencemar organik dan bahan bukan organic (Byungryul *et al.*, 2018). Kaedah ini amat berguna untuk menjerap sesuatu komponen jisim ke permukaan mereka. Penggunaan penjerap seperti karbon teraktif (Li *et al.,* 2020; Nejadshafiee & Islami, 2019); lignoselulosa (Freitas *et al.*, 2019) dan kaolin (Mustapha *et al.,* 2019) mempunyai banyak kelebihan berbanding dengan proses-proses lain. Penjerapan dianggap sebagai kaedah yang cekap dan serba boleh, baik terhadap jenis air sisa yang berbeza, murah dan mudah pengoperasiannya.

1.2 Pernyataan Masalah

Masalah utama industri getah asli mentah ini ialah penghasilan air sisa yang berbahaya, pencemaran udara dan pengurusan sisa pepejal. Dari semua masalah ini, air sisa merupakan masalah utama dengan menghasilkan sejumlah besar air sisa dari operasi pemprosesannya. Air sisa getah asli mentah ini mengandungi COD, BOD, ammoniakal nitrogen dan pepejal terampai yang tinggi (Massoudinejad *et al.*, 2015). Bahan pencemar yang lain adalah seperti nitrat dan fosforus. Hasil kajian pencirian yang lepas (Watari *et al.*, 2017; Chankachang *et al.*, 2016) mendapati kandungan air sisa getah asli ini melepasi had pelepasan yang dibenarkan mengikut Peraturan-Peraturan Kualiti Alam Sekeliling (Getah Asli Mentah) 1978. Tanpa rawatan yang betul, pembuangan air sisa getah asli mentah ke persekitaran boleh menyebabkan kesan yang serius kepada kesihatan manusia dan alam sekitar.

Kebanyakkan rawatan air sisa getah asli mentah ini menggunakan teknologi kolam anaerobik dan fakultatif yang mempunyai beberapa kekurangan dan kelemahan seperti memerlukan kawasan tanah yang luas, kos operasi yang tinggi, masa tahanan yang lebih lama dan pelepasan gas metana (Wang *et al.*, 2017). Peningkatan pemprosesan ini akan menyebabkan bilangan dan keluasan kolam sedia ada tidak dapat menampung proses rawatan. Ini akan menyebabkan masalah pencemaran air dan bau yang tidak menyenangkan kepada penduduk yang berdekatan dan ditambah lagi oleh masa rawatan yang lebih lama menyebabkan jumlah besar air harus disimpan dari masa ke masa. Oleh itu perlunya mencari kaedah baharu yang cekap, cepat dan berkesan dalam meningkatkan kualiti rawatan air sisa getah asli dengan teknik-teknik yang lebih inovatif (Mohammadi *et al.*, 2013)

Teknologi penjerapan dilihat sebagai altenatif untuk rawatan air sisa getah asli mentah ini. Kajian terdahulu juga menunjukkan penggunaan kaedah penjerapan tunggal ini dapat menyingkirkan warna, COD dan NH_3-N dari air sisa (Umudi & Awatefe 2018; Huang *et al.*, 2017). Namun begitu, didapati penjerap tunggal mempunyai kelebihan dan kekurangan masing-masing dari segi keupayaan penjerapan. Oleh itu, kekurangan yang ada pada penjerap tunggal boleh diatasi dengan menggabungkannya menjadi penjerap komposit dalam merawat air sisa getah asli mentah yang mengandungi pencemar utama COD, ammoniakal nitrogen dan warna.

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VITA

Pengarang dilahirkan pada 25 Jun 1970 di Kajang, Selangor, Malaysia. Beliau menerima pendidikan rendah di Sekolah Kebangsaan Leftenan Adnan (1976-1977), Sekolah Kebangsaan Petaling (1978-1982) dan Sekolah Menengah Kebangsaan Petaling (1973-1987). Beliau melanjutkan pelajarannya di Politeknik Port Dickson dalam Sijil Senibina bermula tahun 1991-1993. Pada tahun 1994, beliau melanjutkan pengajian di Universiti Teknologi Malaysia, Johor dalam Ijazah Sarjana Muda Kejuruteraan Awam. Selepas melengkapkan ijazahnya pada tahun 1997, beliau sekali lagi mengejar Ijazah Sarjana Pendidikan Teknikal di Universiti Teknologi Malaysia, Johor dan lulus dengan jayanya pada tahun 1999. Pada Jun 1999, beliau telah dilantik sebagai pensyarah di Politeknik Kuching Sarawak dan bertukar ke Politeknik Port Dickson pada Jun 2004. Sebagai seorang yang bersemangat, kreatif dan berdedikasi tujuannya adalah untuk menuntut ilmu sepanjang hayat. Pada tahun 2014 beliau menyambung pelajaran ke doktor falsafah dalam bidang kejuruteraan awam khusus dalam kejuruteraan alam sekitar di Universiti Tun Hussein Onn Malaysia dan dijangkasiap pada tahun 2021. Sepanjang kajian doktor falsafah ini, beliau menghadiri beberapa persidangan antarabangsa dan berjaya menerbitkan beberapa jurnal indeks scopus.