CHARACTERIZATION AND KINETICS STUDY OF ACTIVATED COCONUT SHELLS, COW BONES AND ZEOLITE BASED ADSORBENT FOR POME TREATMENT

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A thesis submitted in
Fulfillment of the requirement for the award of the
Doctorate Degree of Philosophy of Civil Engineering

Faculty of Civil and Environmental Engineering
Universiti Tun Hussein Onn Malaysia

JANUARY 2018

DEDICATION

This project is dedicated to Almighty Allah, the maker of all things and to my family especially my parents Mr. and Mrs. Adeleke who have being the pillar of my life from cradle.

ACKNOWLEDGEMENT

I wish to express my profound gratitude to Almighty Allah who has made my studies to be possible overseas. I would like to extend my gratitude to my supervisor Prof. Ab Aziz Abdul Latiff for his guide, support, motivation and mentorship and for giving me the platform and opportunity to pursue this research. I cannot quantify my gratitude Prof, may Allah reward you abundantly. I am also thankful to my Co- Supervisor, Assoc. Prof Zawawi Daud for his assistance and encouragement and other members on my research team.

I wish to acknowledge both the academic and non-academic staff of the Faculty, my sincere thanks go to my Head of Department, Assoc. Prof. Mohammed Adib Mohd Razi, Deputy Dean of research and innovation, Associate Professor Norzila Othman, Director of micropollutant research center (MPRC) Associate Professor Radin Maya Mohammed Saphira and all the staff of water and environmental engineering.

I also wish to extend my gratitude to the science officers and colleagues; Falilah Mat Daud, Mohammed Nda, Dr Arif Rosli, Mahmood Hijab, Vicky Kumar, Mohammed Kabir and others. Thank you and God bless you all. I appreciate the assistance and patience granted to me by the laboratory technician of MPRC to use the laboratory facilities even beyond the official hours. I will not forget to thank the cleaners who made the workstation to be habitable throughout my study period.

My special gratitude goes to my family members, my father, my mother, siblings and my fiancée (AbdulKareem Robiah). Thank you for your support. Your love and care is well acknowledged. I really appreciate all the kind gestures, motivation and prayers. May Allah reward you all with long life and prosperity.

Finally, I would like to express my gratitude to the office of research, innovation and commercialization center (ORICC) Universiti Tun Hussein Onn Malaysia for making my study possible through the support with the research grant (U272).

ABSTRACT

Palm oil mill effluent (POME) is a high strength agro-allied wastewater containing both organic pollutants and heavy metals. The discharge of POME into the environment without adequate treatment contributes to diseases affecting humans and aquatic lives. However, there is the necessity to reduce the pollutants to a very low level of discharge to reduce the impact of the toxic effect of the pollutants on the environment and the aquatic population. The conventional approach for the treatment of POME is expensive compared to the method of adsorption. The method of adsorption has shown to be cost and time effective for research. Thus, the objective of this study was to prepare composite adsorbent from activated coconut shell carbon (ACSC), activated cow bone powder (ACBP) and zeolite for the treatment of POME using the optimum particle size obtained in a batch adsorption study. The characterization of the ACSC, ACBP and zeolite was obtained using pendant drop contact angle experiment. The result illustrated that the contact angles of the ACSC, ACBP and zeolite respectively were 105.20^{o}, 95.70^{o} and 25. 20^{o}. The result of the contact angles showed that activated coconut shell carbon and activated cow bone powder were hydrophobic materials while the zeolite was hydrophilic. The investigation of the chemical composition of the materials using energy dispersive x-ray (EDX) indicated that the major elements of both ACSC and ACBP were predominantly C, Ca^{2+} and O and Si for zeolite and C, Si, O, Na, Mg, Ca and P as the major elements on the surface of the composite while the XRF showed that the composite contained CaO and SiO_2 as the major compounds. The point of zero charge (pH_{pzc}) of 5.28 achieved showed that the composite contained acidic surface which influenced cationic exchange in the supernatant and the surface of the composite. The CEC after adsorption was observed as 0.8918±0.0669 meq/g. The optimal batch adsorption of COD and NH_3-N was obtained at under fixed condition of pH 7, 105 minutes contact time at 150 rpm shaking speed and 150 µm particle size for ACSC,

ACBP and zeolite. The prepared composite adsorbent contained functional groups of CH, C=C, C-O-C, OH using the Fourier transform irradiation (FT-IR) analysis. The optimal operation parameters of the adsorption process for the reduction of COD and NH_3-N using the central composite design (RSM) was recorded at pH 10, 50 rpm of shaking speed for 2 h and by using 3 mm of composite particle size and 125 gL^{-1} of the adsorbent at initial concentration of POME of 1 ml per 500 ml volumetric flask. The results revealed that the investigated factors evidently induced the reduction of the parameters. The experimental data of COD, NH_3-N, Cd, Fe and Pb from the batch study were fitted to the isotherm and kinetic models. The result of the isotherm study fitted best to the Langmuir equation model for COD, NH_3-N, Fe and Cd which indicated that the adsorption of the pollutants from the supernatant was favourable on a mono layer surface. The Frendlich isotherm fitted experimental data better than the Langmuir and the Temkin isotherm for Pb which showed that the adsorption process was effective on a heterogeneous surface. The investigation showed that the uptakes of COD, NH_3-N, Cd, Fe and Pb from the experimental data were fitted to the pseudo-second order kinetic model which implied that the process of adsorption was by chemisorption. Furthermore, the fixed bed packed composite adsorption was conducted and the experimental data were fitted to Thomas and Adams-Bohart model. The model parameters were obtained from the breakthrough curves, the effective adsorption of COD was obtained at lower flow rate influent concentration. Desorption of the spent adsorbent was suitably conducted using 0.5M NaOH and breakthrough was obtained at longer retention time. It can be concluded that a mesoporous and granular composite adsorbent was effective for the treatment of both organic and heavy metal pollutants. It was observed that both batch isotherm and kinetic study can be effectively applied for the treatment of POME using the composite adsorbent, although the effectiveness of the batch adsorption study showed to be more suitable than the fixed bed continuous column for the removal of pollutants of POME. However, due to the potential of the composite adsorbent for the treatment of POME, the treatment efficiency of the adsorbent has shown that the composite have the potential to be used for the treatment of pollutants of high strength wastewater.

ABSTRAK

Efluen kilang minyak kelapa sawit (POME) adalah air sisa agro-pertanian yang mengandungi bahan pencemar organik dan logam berat. Pelepasan POME ke dalam persekitaran tanpa rawatan yang mencukupi menyumbang kepada penyakit yang memberi kesan kepada manusia dan kehidupan akuatik. Walau bagaimanapun, terdapat keperluan untuk mengurangkan pencemaran kepada tahap pelepasan yang sangat rendah untuk meminimumkan kesan pencemar toksik terhadap alam sekitar dan populasi akuatik. Pendekatan konvensional untuk rawatan POME adalah mahal berbanding kaedah penjerapan. Kaedah penjerapan telah menunjukkan kos dan masa yang berkesan untuk penyelidikan. Oleh itu, objektif kajian ini adalah untuk menyediakan penjerap komposit daripada karbon teraktif tempurung kelapa (ACSC), serbuk tulang lembu teraktif (ACBP) dan zeolit untuk rawatan POME menggunakan saiz partikel optimum yang diperolehi dalam ujikaji penjerapan kelompok. Pencirian ACSC, ACBP dan zeolit diperoleh dengan menggunakan ujikaji sudut sentuhan titis loket. Hasil keputusan menggambarkan bahawa sudut sentuhan ACSC, ACBP dan zeolit masing-masing adalah 105.20^{o}, 95.70^{o} dan 25.20^{o}. Hasil daripada sudut sentuhan menunjukkan bahawa karbon teraktif tempurung kelapa dan serbuk tulang lembu teraktif adalah daripada bahan hidrofobik manakala zeolit adalah daripada bahan hidrofilik. Penyiasatan komposisi bahan kimia yang menggunakan sinaran-x penyebaran tenaga (EDX) menunjukkan bahawa unsur-unsur utama ACSC dan ACBP adalah terutamanya C, Ca^{2+} dan O dan Si untuk zeolit dan C, Si, O, Na, Mg, Ca dan P sebagai unsur utama pada permukaan komposit manakala XRF menunjukkan bahawa komposit mengandungi CaO dan SiO_2 sebagai sebatian utama. Titik caj sifar (pH_{pzc}) adalah 5.28 telah dicapai menunjukkan bahawa komposit mengandungi permukaan berasid yang mempengaruhi pertukaran kationik dalam supernatan dan permukaan komposit. CEC selepas penjerapan diperhatikan sebagai 0.8918 ± 0.0669 meq/g. Penjerapan kelompok optimum COD dan NH_3-N didapati dalam keadaan tetap iaitu pH 7, 105 minit masa sentuhan pada kelajuan goncangan 150 rpm dan saiz partikel 150μm untuk ACSC, ACBP dan zeolit. Penjerap komposit yang disediakan

mengandungi kumpulan berfungsi CH, C=C, C-O-C, OH menggunakan analisis radiasi transformasi Fourier (FT-IR). Parameter optimum operasi bekerja bagi proses penjerapan untuk penurunan COD dan NH_3-N menggunakan reka bentuk komposit pusat (RSM) direkodkan pada pH 10, kelajuan goncangan 50 rpm selama 2 jam dan menggunakan 3 mm saiz partikel komposit dan 125 gL^{-1} dari penjerap pada kepekatan awal POME 1 ml terhadap 500 ml kelalang volumetrik. Hasil keputusan didapati bahawa faktor-faktor yang dikaji secara jelasnya mendorong terhadap penurunan parameter. Data eksperimen COD, NH_3-N, Cd, Fe dan Pb dari ujikaji kelompok dipadankan dengan model isoterma dan kinetik. Hasil kajian padanan isoterma terbaik adalah model persamaan Langmuir untuk COD, NH_3-N, Fe dan Cd yang menunjukkan bahawa penjerapan bahan pencemar dari supernatan adalah digemari pada permukaan lapisan tunggal. Data eksperiman daripada isoterma Freundlich yang dipadankan adalah lebih baik daripada isoterma Langmuir dan Temkin untuk Pb yang menunjukkan bahawa proses penjerapan berkesan pada permukaan yang heterogen. Penyiasatan didapati menunjukkan bahawa pengambilan COD, NH_3-N, Cd, Fe dan Pb daripada data eksperimen telah dipadankan dengan model kinetik pseudo-tertib kedua yang menunjukkan bahawa proses penjerapan adalah secara penjerapan kimia. Seterusnya, penjerapan komposit lapisan tetap yang telah dijalankan dan data eksperimen berikut telah dipadankan dengan model Thomas dan Adams-Bohart. Parameter model telah diperolehi daripada lengkung bulus, penjerapan COD yang berkesan ditunjukkan melalui kadar aliran yang lebih rendah. Penjerapan semula penjerap telah dilakukan dengan menggunakan 0.5M NaOH dan bulus didapati pada masa tahanan yang lebih lama. Secara kesimpulannya didapati bahawa penjerap komposit mesoliang dan butiran adalah berkesan untuk merawat kedua-dua bahan pencemar organik dan logam berat. Telah diperhatikan bahawa kajian isoterma dan kinetik kedua-duanya secara berkesan boleh digunakan untuk rawatan POME dengan menggunakan penjerap komposit, walaupun keberkesanan ujikaji penjerapan kelompok menunjukkan ianya lebih sesuai daripada turus penjerapan lapisan tetap untuk penyingkiran bahan pencemar POME. Walau bagaimanapun, disebabkan oleh potensi penjerap komposit untuk rawatan POME, kecekapan rawatan penjerap telah menunjukkan bahawa penjerap komposit mempunyai potensi untuk digunapakai dalam rawatan pencemaran air sisa berkekuatan tinggi.

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A	Binding surface area
B	Temkin constant
B	Blank
Ce	Final equilibrium concentration
C_O	Initial concentration
CO	Cobalt
Cv	Crystal violet
Cu	Copper
Cr	Chromium
Cd	Cadmium
C_T	Outlet concentration
D	Dilution factor
Fe	Iron
H	Initial rate of adsorption
K	Kinetic constant
K_f	Adsorbent adsorbed per unit equilibrium
Ki	Intraparticle diffusion rate constant
K_L	Langmuir constant
K_T	Temkin constant
K_{TH}	Thomas rate constant
Kyn	Rate constant
L	Liter
Lb	Pound
Ft	Feet
M	Mass
mg/L	Milligram per liter
Mn	Manganese
N	Total available sites
N	Freundulich slope
Ni	Nickel
Ns	Number of sites occupied

P	Pressure
P^o	Vapour pressure
Q	Flow rate
q_e	Quantity of the adsorbed per unit mass of adsorbent
q_o	Maximum solid phase concentration of the solute
q_t	Amount of the adsorbed per unit time
R	Gas constant
R_L	Separation coefficient
T	Temperature
S	Sample
U	Speed of gas out
V	Volume of solution
V_{eff}	Volume of effluent
Vε	Volume porosity
X	Amount of adsorbent in the column
W	Weight of adsorbent
Z	Column bed height
Λ	Time required for breakthrough at 50%
>	Greater than
<	Less than
°	Degree
AAS	Atomic analyst spectrometer
AF	Activated carbon
ACBP	Activated cow bone powder
ACSC	Activated coconut shell carbon
AF	Anaerobic filter
ASB	Activated sludge biomass
ASBR	Anaerobic sequencing batch reactor
ATA	Attapulgate composite
BDDT	Brunauer, Deming, Deming Teller
BDOC	Biodegradable organic compound
BET	Brunauer Emmet and Teller
BOD	Biochemical oxygen demand
BF	Basil Fuchsin
CA	Catalytic activity
CBP	Cow bone powder

CCD	Central composite design
COD	Chemical oxygen demand
CPW	Crude petroleum wastes
CR	Congo red
CV	Crystal violet
DOE	Department of Environment
DKR	Dubinin-Kagener Radushkevich
EBCT	Empty bed contact time
EDX	Energy dispersive x-ray
EF	Electron –Fenton process
EFB	Empty fruit bunches
EPA	Environmental protection agency
FAS	Ferrous ammonium sulphate
FO	Forward osmosis
FTIR	Fourier transform irradiation
GAC	Granular activated carbon
GCF	Global contamination factor
HAP	Hydroxyapatite
ICF	Individual contamination factor
ICP-MS	Inductively coupled plasma mass spectrometry
INWQS	Interim water quality standard
MAS	Membrane anaerobic system
MB	Methylene blue
MF	Micro filtration
MO	Methyl orange
MSDS	Material safety and data sheet
MTZ	Mass transfer zone
NF	Nano filtration
OLR	Organic loading rate
OPC	Ordinary Portland cement
OPF	Oil palm fronds
OPT	Oil palm trunk
PAC	Powdered activated carbon
PCB	Poly chlorinated biphenyls
POME	Palm oil mill effluent
POMS	Palm oil mill sludge
POFA	Palm oil fuel ash
PPB	Part per million
PPF	Palm processed fibers
PSAC	Palm shell activated carbon
PVA	Polyvinyl alcohol

RO	Reverse osmosis
RSM	Response surface methodology
SEM	Scanning electron microscopy
SS	Suspended solids
SWOT	Strength, opportunity, weakness and threat
TN	Total nitrogen
TOC	Total organic carbon
TS	Total solids
TSS	Total suspended solids
UASB	Up-flow anaerobic sludge blanket
UASFF	Up flow anaerobic sludge fixed film
UF	Ultra filtration
VSS	Volatile suspended solids
WAS	Waste activated sludge
WHO	World Health Organization

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