REMOVAL OF MALACHITE GREEN BY MIXTURE OF TEXTILE SLUDGE AND SAWDUST CHEMICALLY PRODUCED ACTIVATED CARBON

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ABSTRACT

The growing Malaysian textile industry has resulted in generation of large quantity of textile sludge and its disposal problem has become a critical environmental issue. Textile sludge based activated carbon (TSAC) derived using potassium hydroxide and potassium iodide chemical activation is a promising route for removal of dyes and it can also mitigate the sludge disposal complication. However, the optimum conditions of TSAC preparation and its applicability in the fixed bed adsorption process has yet to be examined. The purpose of this study is to investigate the potential of utilizing TSAC and its pellet (prepared using phosphoric acid impregnated sawdust as a binder) as adsorbents for malachite green (MG) removal in batch and continuous adsorption system. The impregnation ratio was varied (0-2) and the impregnated samples were activated at optimum temperature and time. The physicochemical properties of the TSACs were characterized using Fourier transform infrared spectroscopy, Brunauer-Emmett-Teller (BET) surface area, Scanning Electron Microscope and CHNOS elemental analyzer. The BET surface area and microporosity of TSACs were in the range of 333-1037 m^2/g and 27-64%, respectively. The TSACs were capable of removing 77-498 mg/g of MG. The Langmuir model gave the best conformity, suggesting a possible monolayer adsorption. The kinetics experimental data were best fitted to the pseudo-second-order model. The intraparticle diffusion model shows that intraparticle diffusion is not the sole rate-limiting step, while the Boyd model reveals that film diffusion could be the rate controlling step. The adsorption of MG onto TSAC is endothermic and spontaneous by nature. Furthermore, H_3PO_4-impregnated sawdust waste, a potential low-cost binder, yielded TSAC pellets with microporosity, surface area and compressive strength of 16-23%, 668-979 m^2/g and 0.4-1.5 MPa, respectively. In addition, the fixed bed adsorption of MG showed that the breakthrough time increased with increasing bed height, and decreasing flow rate and influent dye concentration. The highest bed capacity of 565 mg/g was achieved at influent concentration of 50 mg/L, flow rate of 20 mL/min and bed height of 6 cm (0.954 g). Yoon-Nelson model was the most suitable in describing the dynamic adsorption behavior of the column. This study demonstrated the potential of H_3PO_4-impregnated sawdust waste as a low-cost binder and the applicability of TSAC in MG adsorption for batch and column operations.

ABSTRAK

Industri tekstil Malaysia yang semakin berkembang telah mengakibatkan penjanaan enapcemar tekstil yang banyak dan masalah pelupusannya menjadi isu alam sekitar yang kritikal. Karbon teraktif berasaskan enapcemar tekstil (TSAC) melalui pengaktifan kimia kalium hidroksida dan kalium iodida merupakan laluan berpotensi untuk penyingkiran pencelup dan ia juga boleh mengurangkan kesukaran pelupusan enapcemar. Bagaimanapun, keadaan optimum penyediaan TSAC dan penggunaannya dalam proses penjerapan lapisan tetap masih belum dikaji. Kajian ini bertujuan menyiasat potensi penggunaan TSAC dan peletnya (yang disediakan menggunakan habuk gergaji diisitepu asid fosforik sebagai pengikat) sebagai penjerap untuk penyingkiran malacit hijau (MG) dalam sistem penjerapan berkelompok dan berterusan. Nisbah pengisitepuan dipelbagaikan (0-2) dan sampel diisitepu diaktifkan pada suhu dan masa yang optimum. Sifat-sifat fizik-kimia TSAC dicirikan menggunakan spektroskopi inframerah jelmaan Fourier, luas permukaan Brunauer-Emmett-Teller (BET), mikroskop elektron imbasan dan analisis unsur CHNOS. Luas permukaan BET dan kandungan liang mikro TSACs masing-masing adalah berada dalam lingkungan 333-1037 m^2/g dan 27-64 %. TSAC mampu menjerap 77-498 mg/g MG. Model isoterma Langmuir memberikan pematuhan terbaik, menunjukkan bahawa penjerapan bersifat satu lapisan. Data ujikaji kinetik memberikan penyesuaian terbaik dengan model pseudo-tertib-kedua. Model resapan antara zarah menunjukkan bahawa resapan antara zarah bukan langkah kadar-penentu tunggal, manakala model Boyd mendedahkan bahawa resapan filem boleh menjadi langkah kawalan kadar. Penjerapan MG ke atas TSAC bersifat endotermik dan spontan secara semula jadi. Selain itu, sisa habuk gergaji diisitepu H_3PO_4 merupakan pengikat berkos rendah, menghasilkan pelet TSAC dengan liang mikro, luas permukaan dan kekuatan mampatan masing-masing adalah sebanyak 16-23 %, 668-979 m^2/g dan 0.4-1.5 MPa. Di samping itu, penjerapan turus tetap MG menunjukkan bahawa masa pembolosan meningkat dengan peningkatan ketinggian turus, dan penurunan kadar aliran dan kepekatan aliran pencelup. Kapasiti turus tertinggi sebanyak 565 mg/g dicapai pada kepekatan aliran 50 mg/L, kadar aliran 20 mL/min dan ketinggian turus 6 cm (0.954 g). Model Yoon-Nelson paling sesuai untuk menggambarkan kelakuan penjerapan dinamik turus. Kajian ini membuktikan potensi buangan habuk gergaji diisitepu H_3PO_4 sebagai pengikat kos rendah dan kebolehgunaan TSAC dalam penjerapan MG untuk operasi berkelompok dan turus.

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LIST OF ABBREVIATIONS

AC	-	Activated Carbon
ACF	-	Activated Carbon Fiber
ACP	-	Activated Carbon Pellets
BDST	-	Bed Depth Service Time
BET	-	Brunauer-Emmett-Teller
BOD	-	Biochemical Oxygen Demand
C	-	Carbon
CI	-	Color Index
Cl_2	-	Chlorine
CMC	-	Carboxymethyl Cellulose
CO	-	Carbon Monoxide
CO_2	-	Carbon Dioxide
COD	-	Chemical Oxygen Demand
DO	-	Dissolved Oxygen
ETAD	-	Ecological and Toxicological Association of Dyes and Organic Pigments Manufacturers
FTIR	-	Fourier Transform Infrared Spectroscopy
GAC	-	Granular Activated Carbon
H_2	-	Hydrogen
H_2O	-	Water
H_2O_2	-	Hydrogen Peroxide
H_3PO_4	-	Phosphoric Acid
IR	-	Impregnation ratio
K_2CO_3	-	Potassium Carbonate
K_2SO_4	-	Potassium Sulfate
KBr	-	Potassium Bromide
KCl	-	Potassium Chloride
KCOOH	-	Potassium Acetate
KOH	-	Potassium Hydroxide

LD50	-	Lethal Dose at 50% survival
MBBR	-	Moving Bed Biofilm Reactor
MG	-	Malachite green
MTZ	-	Mass Transfer Zone
N_2	-	Nitrogen
NaCl		Sodium Chloride
NaOH	-	Sodium Hydroxide
O_2	-	Oxygen
PAC	-	Powdered Activated Carbon
PAIS	-	Phosphoric Acid (H_3PO_4) Impregnated Sawdust
PAN	-	Polyacrylonitrile
RO	-	Reactive Orange
RSM	-	Response Surface Methodology
SEM	-	Scanning Electron Microscope
T&C	-	Textile and Clothing
TS		Textile Sludge
TSAC	-	Textile Sludge based Activated Carbon
UV-Vis	-	Ultraviolet-Visible Spectroscopy Diffuse
$ZnCl_2$	-	Zinc Chloride

LIST OF SYMBOLS

%	-	Percent
atm	-	Atmospheric Pressure
cm^2	-	Centimeter Square
cm^3	-	Centimeter Cube
g	-	Gram
GHz	-	Gigahertz
h	-	Hour
J	-	Joules
K	-	Kelvin
kg	-	Kilogram
L	-	Liter
m^2	-	Meter Square
m^3	-	Meter Cube
mg	-	Miligram
min	-	Minute
mL	-	MiliLiter
mmol	-	Milimoles
nm	-	Nanometer
^oC	-	Degree Celcius
ppm	-	Parts Per Million
s	-	Second
S_{BET}	-	BET Surface Area
ųm	-	Micrometer
W	-	Watt
λ_{max}	-	Maximum Wavelength

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Over the years, water pollution control has been a subject of great interest. Manufacturing industries such as textile, paper and leather are major productions that employ dyes and other chemical agents in their process. It is necessary to separate these contaminants from the wastewater prior to its release. The removal of dyes from effluents can be strenuous because most of them are stable to light, heat and oxidizing agents and biologically non-degradable (Abrahart, 1977). Nevertheless, the accelerating growth of Malaysia's textiles and apparel industry (Idris *et al.*, 2007) has led to a higher demand of dyes and improper handling of dye effluent can result in a serious threat to receiving water bodies.

Dyes are chemical compounds that can associate themselves to surfaces or fabrics to impart colour. Malachite green (MG) is a blueish green cationic dye which is widely used in global textile and clothing industry and aquaculture manufacturing as a biocide, despite of being carcinogenic and genotoxic. This colorant is very soluble in water but is resistant to exposure of light, causing difficult separation from industrial effluents via conventional chemical and biological treatment. By exploiting its high solubility in water, MG can be easily eliminated from wastewater through adsorption process using solid adsorbents or activated carbon (Gouranchat, 2000; Baek *et al.*, 2010). Thus, more research and studies should be focused on the removal of MG from water bodies to maintain the water quality and health of living beings.

There are many physical and chemical treatment technologies that can be applied for dye removal wastewater, for instance ion exchange, flocculation and coagulation, membrane filtration, oxidation and electrolysis. Adsorption process an effective and inexpensive method as it utilizes low cost adsorbents and no sludges are produced (Hena, 2010). In other words, adsorption is an excellent choice for dye removal in terms of initial cost, simplicity of design, ease of operation and insentivity to toxic substances.

Textile sludge (TS) is a potential adsorbent material for the production of activated carbon in dye removal owing to its high carbon content, inert towards toxic substance and low initial cost (Kacan, 2016; Tang and Zaini, 2017). In practice, the preparation of activated carbon can be carried out in two methods which are chemical activation and physical activation. In chemical activation, the raw material is initially subjected to impregnation with activating agents like KOH, NaOH or K_2CO_3 before thermal activation. Chemical activation prevails over physical activation due to its higher surface area and pore development, short activation time, low activation temperature and higher yield (Katesa *et al.*, 2010; Patil and Kulkami, 2012). The textile sludge based activated carbon (TSAC) prepared via KI+KOH activation has high surface area and MG adsorption capacity of 481 m^2/g and 167 mg/g, compared to KI activated TSAC (123 m^2/g and 37 mg/g) and KOH activated TSAC (301 m^2/g and 108 mg/g) (Tang and Zaini, 2017). Composite KI+KOH activating agent has shown promising outcome and further study should be done.

The conversion of powdered activated carbon (PAC) into different shapes (cylindrical, pellets, spherical, ring, etc.) is crucial in many industrial applications like adsorption and catalyst support as they possess good compressive strength and high volumetric adsorption capacity and ease transportation problem. Activated carbon pellet (ACP) can be fabricated by extruding PAC together with a binder, in order to hold the carbon particles in a stable compressed state. The binder ought to (a) produce ACP with good compression strength with lowest binder/AC ratio to maximize the quantity of AC, (b) retain or enhance the specific surface area of AC (does not trigger pore blocking). H_3PO_4-impregnated waste sawdust (PAIS) is a promising and cost-effective binder as the PAC produced has good surface area and mechanical strength (Li *et al*., 2014a; Li *et al*., 2014b).

Continuous fixed bed column operations are vastly implemented in various industrial and pollution control processes like treatment of dye wastewater via a fixed bed of carbon adsorbent, gas or liquid catalytic reaction by structured catalyst bed and separation of ions by a packed ion-exchange resin bed. Column adsorption study is crucial as involves the investigation of other operational complications including irregular flow rate in column, underperformance of adsorbents in continuous system, recycling and regeneration of spent adsorbent (Gopal *et al*., 2016). Unlike batch adsorption, fixed bed column adsorption may not run under equilibrium state due to insufficient time to achieve equilibrium adsorption (Gopal *et al*., 2016, Yagub *et al*., 2015). Precise modelling and simulation of the dynamic pattern of fixed bed systems is indispensable in designing an optimal column sorption process. Over the years, a few models were formulated based on fundamental mass transport mechanism (surface, pore and film diffusion) for the prediction of different adsorption systems. In order to save time and cost, the pilot plant testing can be done by applying shortcut models - bed service time (BDST) model (Hutchins, 1973) and mass transfer zone (MTZ) model (Michaels, 1952) which provide straightforward method and fast estimation of adsorber performance (Markovska *et al*., 2001). The bed service time (BDST) model has been effectively employed to report and anticipate the column adsorption of dye using various adsorbents (Markovska *et al*., 2001, Gopal *et al*., 2016, Yagub *et al*., 2015). In this work, four mathematical models - Bohart-Adams, Thomas, Yoon Nelson and Clark models are used to construct the column breakthrough curves of adsorbent and explain the mechanism of fixed bed column adsorption.

Response surface methodology (RSM) is a group of mathematical and statistical approaches which is extensively used in the industrial field to develop, improve and optimize processes (Myers *et al*., 2016, Xue *et al*., 2016). The empirical model building involves the measurement of output response (output variable) or performance measure affected by several potential independent variables (input variables) on a continuous scale. The researcher or engineer can control and manipulate the input variables of an experiment or test. More than one response variables are usually incorporated in the majority of industrial RSM applications (Myers *et al*., 2016). A series of tests or runs are carried out using different sets of input variables to determine the output response and identify the rationale behind its changes (Raissi and Farsani, 2009).

In short, the growing menace of water pollution has always been the centre of concern. With the discovery of TSAC, the environmental pollution can be cut down twice the scale as this will not only assist greatly in water treatment technology, but also reduce the need of landfill and incineration and thereby averting both water and land pollution. Moreover, H_3PO_4-impregnated sawdust waste is a potential low-cost binder, which also contributes to the conversion of waste into reusable material. This study is expected to contribute further understanding on dye wastewater treatment using TSAC in industrial scale.

1.2 Problem Statement

Synthetic textile fiber is a popular industry in Malaysia. There are 662 licensed and 1000 small scale textile and apparel factories in 2012 (Malaysian Investment Development Authority (MIDA), 2012). Johor (28.6 %) was found to be the highest contributing source of the textile industrial wastewater pollution, followed by Penang (28.2 %) and Selangor (15.6 %) (Muyibi *et al.*, 2008). Malaysian textile industries treat its own wastewater and the treated effluent should comply with the discharge limit before emission. This would in turn generate large amount of sludge which requires further handling and disposal (Pang and Abdullah, 2013). The Malaysia Department of Environment classifies sludge produced from wastewater treatment plants as scheduled waste and should be disposed of under a prescribed premise only (Hanum *et al.*, 2019). The total quantity of scheduled waste generated by textile industry surged from 744 tons (2007) to 1559 tons (2009) (Pang and Abdullah, 2013) and the estimated total cost of managing sewage sludge in Malaysia is RM1.38 billion per year (Kadir and Mohd, 1998). The generation of large amount of sludge and its disposal problem has become a critical environmental issue. Thus, the conversion of textile sludge into activated carbon can reduce the sludge disposal problem and at the same time preserve the environment. The carbon content of textile sludge is in the range of 23-42.3 % (Kacan, 2016; Sohaimi and Ngadi, 2016; Tang and Zaini, 2017), indicating it can be used as a precursor for the preparation of AC.

Adsorption using activated carbon is an effective physical treatment for dye wastewater. Studies have reported the generation of TSACs through different methods, but their surface area were only 195-481 m^2/g. In one of the studies, the composite KI+KOH activating agent had successfully converted TS into TSAC. The TSACs activated at 0.7:0.3:1 (KI:KOH:TS), 500 ^oC and 1 h possessed surface area, microporosity and MG adsorption capacity of up to 481 m^2/g, 47 % and 167 mg/g, respectively (Tang and Zaini, 2017). Besides that, Kacan (2016) also obtained TSAC with a surface area of 336 m^2/g at activation condition of 0.5:1 (KOH:TS), 700 ^oC and 0.75 h, whereas Sohaimi and co-workers (2017) produced TS biochar with a surface area of only 195 m^2/g at carbonization condition of 700 ^oC and 1 h (without activating agent). Wong and colleagues (2018) chemically activated the TS using H_2SO_4 at condition of 1:1 (H_2SO_4:TS), 650 ^oC and 0.5 h. The H_2SO_4-TSAC has a surface area and microporosity of 222 m^2/g and 63 %. However, these findings are only satisfactory as compared to commercial AC with surface area 820 m^2/g and MG adsorption capacity of 222 mg/g (Malik *et al*., 2007). Moreover, the TSACs also exist in a fluffy powdery form due to its porous nature, resulting in prolonged settling time and cumbersome adsorbent handling. These problems may complicate the scaling up of the adsorption process using TSAC for industrial applications. Up to date, no studies were performed using TSAC in fixed bed column adsorption of MG, most likely due to its powdery form and low surface area.

In the previous study, KI+KOH activation was carried out at fixed temperature and time of 500 ^oC and 1 h, with only three impregnation ratios of 1:1:1, 0.7:0.3:1 and 0.5:0.5:1 (Tang and Zaini, 2017). Therefore, in this study, the TSAC preparation conditions via KI+KOH activation including activation temperature, time and impregnation ratio (KI:KOH:TS) was evaluated to produce the highest achievable surface area of TSAC. Furthermore, the TSAC was also converted into pellet form using the PAIS binder. Although PAIS binder has been used to convert commercial AC powder and peanut shell char into pellets (Li *et al*., 2014; Li *et al*., 2014 b), no studies have attempted to use TSAC powder. Since the base materials used were different, the pellets produced also have different physicochemical properties. The newly improved TSACs and its derivatives were also characterized for their physicochemical properties and adsorption performance. In addition, the fixed bed adsorption column for the removal of MG was also performed and the operating parameters such as bed height, flow rate and influent dye concentration were investigated.

1.3 Objective of the Study

The objectives of this research are:

i. To evaluate the effects of activation temperature, time and impregnation ratio for the production of textile sludge based activated carbon (TSAC) via KI+KOH activation and to characterize the resultant products.
ii. To establish the adsorption isotherms, kinetics and thermodynamics of malachite green (MG) adsorption onto TSAC.
iii. To evaluate the adsorptive and mechanical properties of phosphoric acid (H_3PO_4)-impregnated sawdust as a binder for TSAC pellets.
iv. To investigate the bed height, influent flow rate and initial dye concentration for fixed-bed column adsorption of MG

1.4 Scope of the Study

The scope of this study is divided into four parts. The first scope of study covers the preparation and characterization of textile sludge based activated carbon (TSAC) via KI+KOH activation. The one-factor-at-a-time method was employed to study the effect of activation temperature, time and impregnation ratio on the TSAC surface area. Initially, the activation temperature (400-800 ^{o}C) and time (0.5-2 h) were varied and the adsorption capacity of methylene blue (MB), also known as MB number was used as a rapid assessment of the TSAC surface area and overall adsorptive capacity because the specific adsorbate has yet to be selected at the beginning. As the MB adsorption capacity increases, the surface area also increases because the it correlates with surface area (Joshi, 2015). This method has been widely used for the characterization of activated carbon (Abdullah *et al*., 2001; Nunes and Guerreiro, 2011; Raposo *et al*., 2009; Joshi, 2015; Adibfar *et al*., 2014). Response surface methodology (RSM) was performed additionally to compare with the optimum experimental activation temperature and time. The effect of impregnation ratios (0-2) were later evaluated at the optimum activation temperature and time. The physicochemical properties of synthesized TSACs were determined using BET, FTIR, SEM, Boehm titration, pH_{pzc} and CHNOS analysis. The RSM was not performed concurrently for all three variables because the MB number was used as the overall screening indicator for activation temperature and time only. Moreover, the previous study showed that the best impregnation ratio was 0.7:0.3:1 (KI:KOH:TS), but the activation temperature and time were not investigated (Tang and Zaini *et al*., 2017).

The second part of the scope of study is establishing the adsorption isotherms, kinetics and thermodynamics of malachite green (MG) onto TSAC. MG dye was used as adsorbates and the batch adsorption was performed to evaluate the performance of activated carbon. The equilibrium isotherm was conducted at different initial concentration (20-1000 mg/L) with contact time of 72 h, whereas three concentrations and at varying time intervals were applied for kinetic studies. Isotherm models consist of Freundlich, Langmuir, Temkin and Redlich-Peterson whereas kinetics models include pseudo-first-order, pseudo-second-order, Boyd and intraparticle diffusion. Thermodynamics study was carried out at temperatures between 30 ^oC and 60 ^oC. The thermodynamics model was used to evaluate the parameters of Gibbs free energy (ΔG^o), enthalpy change (ΔH^o) and entropy change (ΔS^o).

The third part of the scope of study includes transforming the powdered TSAC into cylindrical activated carbon pellets by using the H_3PO_4-impregnated sawdust waste (PAIS) binder. The mass ratio of H_3PO_4: sawdust: TSAC was fixed at 1.7:1:0.4. The mixture will be manually extruded into a cylindrical mould and pyrolyzed at 560 ^oC for different time (1 – 3 h) (Li *et al*., 2014a). The TSAC pellets produced were tested for their adsorptive and mechanical properties such as compressive strength, bulk density and ability to maintain its shape in water. The TSAC pellets were used to perform batch adsorption equilibrium experiments.

In order to achieve the fourth scope of study, the TSAC granules were used for the fixed bed adsorption column study. The original powdered TSAC was not applicable in the fixed bed column as the wool could not hold it in place, whereas the size of the pellets (D = 8.5 mm, H = 6.3 mm) was too large resulting in a less favourable column packing and incomplete breakthrough curves (BTC). BTC is the plot of normalized concentration (C_t/C_o) as a function of time, where C_t is the effluent concentration and C_o is the influent concentration (mg/L) (Han *et al*. 2009). A complete sigmoidal or S-shaped BTC can be obtained when the $C_t/C_o \approx 1$, indicating the exhaustion of the adsorbent bed (Afroze *et al*., 2016). A complete BTC is crucial in the analysis of the operational and dynamic behaviour of an adsorption fixed-bed column (Han *et al*. 2009). Therefore, the large TSAC pellets were crushed into tiny granules with average particle size of 0.5 mm. This is because some adsorption column studies reported that complete BTCs were attained using pine cone AC (0.5 mm) (Samarghandi *et al*., 2014) and sludge adsorbent (0.6 mm) (GEPEA Université de Nantes, 2009), whereas larger sized granular zeolite (1.6 mm) (Abu-Lail et al., 2010) and bagasse activated carbon (1.5 mm) (Karunarathne and Amarasinghe, 2013) produced incomplete BTCs. The effect of bed height (2-6 cm), influent flow rate (15-30 mL/min) and initial dye concentration (20-80 mg/L) on the fixed-bed column adsorption of MG using TSAC granules were investigated. The breakthrough curve analysis was also performed. The adsorption column data were fitted into four column models namely Thomas, Yoon-Nelson, Bohart-Adams and Clark model.

1.5 Significance of Study

The growing menace of water pollution has always been the centre of concern. With the discovery of high surface area TSAC, the environmental pollution can be cut down twice the scale as this will not only assist greatly in water treatment technology, but also reduce the use of landfill and sludge incineration and thereby averting both water and land pollution. This study is imperative as it investigates the best conditions to prepare TSAC via KI+KOH activation and explores the improvements of the physical and mechanical properties of TSAC. Besides, H_3PO_4-impregnated sawdust waste is a potential binder, which also contributes to the conversion of waste into reusable material. Moreover, the fixed bed adsorption of MG is also being investigated, whereby the bed height, influent flow rate and initial dye concentration for fixed-bed column adsorption of MG using TSAC were evaluated. This study is expected to contribute further understanding on dye wastewater treatment using TSAC.

REFERENCE

Abdullah, A. H., Kassim, A., Zainal, Z., Hussien, M. Z., Kuang, D., Ahmad, F. and Wooi, O. S. (2001). Preparation and characterization of activated carbon from gelam wood bark (Melaleuca cajuputi). *Malaysian journal of analytical sciences*, *7*(1), 65-68.

Abechi, S. E., Gimba, C. E., Uzairu, A. and Dallatu, Y. A. (2013a). Preparation and Characterization of Activated Carbon from Palm Kernel Shell by Chemical Activation. *Research Journal of Chemical Science, 3*(7), 54-61.

Abechi, S. E, Gimba, C. E, Uzairu, A., Kagbu, J. A. and Ocholi, O. J. (2013b). Equilibrium Adsorption Studies of Methylene Blue onto Palm Kernel Shell Based Activated Carbon. *International Refereed Journal of Engineering and Science, 2*(5), 38-45.

Abrahart, E. N. (1977). *Dyes and Their Intermediates*. London: Edward Arnold Ltd.

Abu-Lail, L., Bergendahl, J. A. and Thompson, R. W. (2010). Adsorption of methyl tertiary butyl ether on granular zeolites: Batch and column studies. *Journal of hazardous materials*, *178*(1-3), 363-369.

Activated Carbon Markets (1994). *Report No. 612*. Cleveland, Ohio: The Freedonia Group. Inc.

Adamson, A. W. and Gast, A. P. (1967). *Physical Chemistry of Surfaces*. (6th ed.). New York: Wiley-Interscience.

Adibfar, M., Kaghazchi, T., Asasian, N. and Soleimani M. (2014). Conversion of Poly(ethylene terephthalate) Waste into Activated Carbon: Chemical Activation and Characterization. *Chem. Eng. Technol., 37*(6), 979-986.

Afroze, S., Sen, T. K. and Ang, H. M. (2016). Adsorption performance of continuous fixed bed column for the removal of methylene blue (MB) dye using Eucalyptussheathiana bark biomass. *Research on Chemical Intermediates*, *42*(3), 2343-2364.

Aharoni, C. and Sparks, D. L. (1991) Kinetics of Soil Chemical Reaction — A Theoretical Treatment. In Sparks, D.L. and Suarez, D.L. (Eds.). *Rates of Soil Chemical Processes*. (pp. 1-18). Madison, Wisconsin: SSSA Special Publication.

Aharoni, C. and Ungarish, M. (1977). Kinetics of Activated Chemisorption. Part 2.—Theoretical Models. *Journal of the Chemical Society, Faraday Transactions 1: Physical Chemistry in Condensed Phases, 73,* 456-464.

Ahmad, A. A. and Hameed, B. H. (2010). Fixed-bed adsorption of reactive azo dye onto granular activated carbon prepared from waste. *Journal of Hazardous Materials*, *175*(1-3), 298-303.

Ahmad, A. L., Harris, W. A. and Ooi, B. S. (2002). Removal of Dye from Wastewater of Textile Industry Using Membrane Technology. *Jurnal Teknologi, 36*(1), 31-44.

Ahmad, M. A., Puad, N. A. A. and Bello, O. S. (2014). Kinetic, equilibrium and thermodynamic studies of synthetic dye removal using pomegranate peel activated carbon prepared by microwave-induced KOH activation. *Water Resources and Industry*, *6*, 18-35.

Ai, L., Huang, H., Chen, Z., Wei, X. and Jiang, J. (2010). Activated Carbon/$CoFe_2O_4$ Composites: Facile Synthesis, Magnetic Performance and Their Potential Application for the Removal of Malachite Green from Water. *Chemical Engineering Journal, 156*(2), 243-249.

Albroomi, H. I., Elsayed, M. A., Baraka, A., and Abdelmaged, M. A. (2017). Batch and fixed-bed adsorption of tartrazine azo-dye onto activated carbon prepared from apricot stones. *Applied Water Science, 7*(4), 2063-2074.

Alderman, D. J. and Clifton-Hadley, R. S. (1993). Malachite Green: A Pharmacokinetic Study in Rainbow Trout, Oncorhynchus mykiss (Walbaum). *Journal of Fish Diseases, 16*(4), 297-311.

Alfaro-Cuevas-Villanueva, R., Hidalgo-Vázquez, A. R., Cortés Penagos, C. D. J. and Cortés-Martínez, R. (2014). Thermodynamic, kinetic, and equilibrium parameters for the removal of lead and cadmium from aqueous solutions with calcium alginate beads. *The Scientific World Journal*, 1-9.

Allen, J. S., McKay, G. and Khader, K. Y. H. (1988). Multi-component Sorption Isotherms of Basic Dyes onto Peat. *Environmental Pollution, 52,* 39--53.

Allen, S. J., Gan, Q., Matthews, R. and Johnson, P. A. (2003). Comparison of Optimized Isotherm Models for Basic Dye Adsorption by Kudzu. *Bioresource Technology, 88,* 143-152.

Alley, E. R. (2007). *Water Quality Control Handbook*. New York: McGraw-Hill.

Allwar, A. (2012). Characteristics of pore structures and surface chemistry of activated carbons by physisorption, ftir and boehm methods. *IOSR J Appl Chem*, *2*(1), 9-15.

AL-Othman, Z.A., Ali, R. and Naushad, M. (2012). Hexavalent Chromium Removal from Aqueous Medium by Activated Carbon Prepared from Peanut Shell: Adsorption Kinetics, Equilibrium and Thermodynamic Studies. *Chemical Engineering Journal, 184*, 238-247.

Altenor, S., Carene, B., Emmanuel, E., Lambert, J., Ehrhardt, J. J. and Gaspard, S. (2009). Adsorption Studies of Methylene Blue and Phenol onto Vetiver Roots Activated Carbon Prepared by Chemical Activation. *Journal of Hazardous Materials, 165*(1-3), 1029-1039.

Alventosa-deLara, E., Barredo-Damas, S., Alcaina-Miranda, M. I. and Iborra-Clar, M. I. (2012). Ultrafiltration Technology with a Ceramic Membrane for Reactive Dye Removal: Optimization of Membrane Performance. *Journal of Hazardous Materials, 209*, 492-500.

Andersen, W. C., Turnipseed, S. B. and Roybal, J. E. (2006). Quantitative and Confirmatory Analyses of Malachite Green and Leucomalachite Green Residues in Fish and Shrimp. *Journal of Agricultural and Food Chemistry, 54*(13), 4517-4523.

Anirudhan, T. S and Radhakrishnan, P. G. (2008). Thermodynamics and Kinetics of Adsorption of Cu (II) from Aqueous Solutions onto a New Cation Exchanger Derived from Tamarind Fruit Shell. *The Journal of Chemical Thermodynamics, 40*(4), 702-709.

Anirudhan, T. S. and Suchithra, P. S. (2010). Equilibrium, Kinetic and Thermodynamic Modeling for the Adsorption of Heavy Metals onto Chemically Modified Hydrotalcite. *Indian Journal of Chemical Technology, 17*, 247-259.

Araneda, C., Basualto, C., Sapag, J., Tapia, C., Cotoras, D., and Valenzuela, F. (2011). Uptake of copper (II) ions from acidic aqueous solutions using a continuous column packed with microcapsules containing a β-hydroxyoximic compound. *Chemical Engineering Research and Design, 89*(12), 2761-2769.

Arivoli, S., Thenkuzhali, M. and Prasath, P. M. D. (2009). Adsorption of rhodamine B by acid activated carbon-Kinetic, thermodynamic and equilibrium studies. *Orbital: The Electronic Journal of Chemistry*, *1*(2), 138-156.

Arulazhagan, P. (2016). A study on Microbial decolourization of Reactive Red M8B by Bacillus subtilis isolated from dye contaminated soil samples. International *Journal of Current Research in Biology and Medicine, 1*(1), 1-13.

Aspland, J.R. (1981). What Are Dyes? What is Dyeing? In American Association of Textile Chemist and Colorist. *Dyeing Primer - Part 1*. (pp. 4-6). North Carolina: Research Triangle Park.

Attar, T., Larabi, L. and Harek, Y. (2014). The inhibition effect of potassium iodide on the corrosion of pure iron in sulphuric acid. *Advances in Chemistry*, 1-5.

Auta, M. and Hameed, B. H. (2011). Preparation of Waste Tea Activated Carbon using Potassium Acetate as an Activating Agent for Adsorption Acid Blue 25 Dye. *Chemical Engineering Journal, 171,* 502-509.

Auta, M. and Hameed, B. H. (2013). Coalesced chitosan activated carbon composite for batch and fixed-bed adsorption of cationic and anionic dyes. *Colloids and Surfaces B: Biointerfaces*, *105*, 199-206.

Auta, M. and Hameed, B. H. (2014). Optimized and Functionalized Paper Sludge Activated with Potassium Fluoride for Single and Binary Adsorption of Reactive Dyes. *Journal of Industrial and Engineering Chemistry, 20,* 830-840.

Ayawei, N., Ebelegi, A. N. and Wankasi, D. (2017). Modelling and interpretation of adsorption isotherms. *Journal of Chemistry*. Article in Press.

Aziz, A. S. A., Manaf, L. A., Man, H. C. and Kumar, N. S. (2014). Column dynamic studies and breakthrough curve analysis for Cd (II) and Cu (II) ions adsorption onto palm oil boiler mill fly ash (POFA). *Environmental Science and Pollution Research*, *21*(13), 7996-8005.

Baek, M. H., Ijagbemi, C. O., Se-Jin, O. and Kim, D. S. (2010). Removal of Malachite Green from Aqueous Solution using Degreased Coffee Bean. *Journal of Hazardous Materials, 176*(1), 820-828.

Bajwa, A., Balakrishnan, M., Svensson, G. and Batra, V. S. (2016). Removal of volatile organic compounds over bagasse ash derived activated carbons and monoliths. *Journal of Environmental Chemical Engineering, 4*(2), 1561-1573.

Bajwa, A., Moraga, F., Balakrishnan, M., Svensson, G. and Batra, V. S. (2015). Activated carbon monoliths by pressureless technique for environmental applications. *Environmental Progress and Sustainable Energy*, *34*(5), 1420-1426.

Bandosz, T. J. (2006). *Activated Carbon Surfaces in Environmental Remediation (Vol. 7)*. Oxford, U.K.: Academic Press.

Banerjee, S. and Sharma, Y. C. (2013). Equilibrium and Kinetic Studies for Removal of Malachite Green from Aqueous Solution by a Low Cost Activated Carbon. *Journal of Industrial and Engineering Chemistry, 19*(4), 1099-1105.

Banerjee, S., Sharma, G. C., Gautam, R. K., Chattopadhyaya, M. C., Upadhyay, S. N., and Sharma, Y. C. (2016). Removal of Malachite Green, a hazardous dye from aqueous solutions using Avena sativa (oat) hull as a potential adsorbent. *Journal of Molecular Liquids, 213*, 162-172.

Baral, S. S., Das, N., Ramulu, T. S., Sahoo, S. K., Das, S. N. and Chaudhury, G. R. (2009). Removal of Cr (VI) by thermally activated weed Salvinia cucullata in a fixed-bed column. *Journal of Hazardous Materials*, *161*(2-3), 1427-1435.

Barka, N., Ouzaouit, K., Abdennouri, M. and El Makhfouk, M. (2013). Dried prickly pear cactus (Opuntia ficus indica) cladodes as a low-cost and eco-friendly biosorbent for dyes removal from aqueous solutions. *Journal of the Taiwan Institute of Chemical Engineers*, *44*(1), 52-60.

Bartram, J. and Balance, R. (1996). *A Practical Guide to the Design and Implementation of Water Quality Studies and Monitoring Programmes*. London: Chapman & Hall.

Bashanaini, M. S., Al-Douh, M. H. and Al-Ameri, H. S. (2019). Removal of Malachite Green Dye from Aqueous Solution by Adsorption Using Modified and Unmodified Local Agriculture Waste. *Science Journal of Analytical Chemistry, 7*(2), 42-56.

Baskaran, P. K., Venkatraman, B. R. and Arivoli, S. (2011). Adsorption of Malachite Green Dye by Acid Activated Carbon-Kinetic, Thermodynamic and Equilibrium Studies. *Journal of Chemistry, 8*(1), 9-18.

Beeckmans, J. M. and Ng, P. C. (1971). Pyrolyzed Sewage Sludge: Its Production and Possible Utility. *Environmental Science and Technology, 5*(1), 69-71.

Bello, O. S., Fatona, T. A., Falaye, F. S., Osuolale, O. M. and Njoku, V. O. (2012). Adsorption of eosin dye from aqueous solution using groundnut hull–based activated carbon: kinetic, equilibrium, and thermodynamic studies. *Environmental Engineering Science*, *29*(3), 186-194.

Ben-Tal, N., Honig, B., Bagdassarian, C. K. and Ben-Shaul, A. (2000). Association entropy in adsorption processes. *Biophysical journal, 79*(3), 1180-1187.

Bhattacharjya, D. and Yu, J. S. (2014). Activated carbon made from cow dung as electrode material for electrochemical double layer capacitor. *Journal of Power Sources*, *262*, 224-231.

Biswas, S., and Mishra, U. (2015). Continuous fixed-bed column study and adsorption modeling: removal of lead ion from aqueous solution by charcoal originated from chemical carbonization of rubber wood sawdust. *Journal of Chemistry*. 1-9.

Boehm H.P. (1994). Some Aspects of the Surface Chemistry of Carbon Blacks and Other Carbons. *Carbon, 32*(5), 759-769.

Bohart, G. S., and Adams, E. Q. (1920). Some aspects of the behavior of charcoal with respect to chlorine. 1. *Journal of the American Chemical Society, 42*(3), 523-544.

Boppart, S. (1996). Impregnated Carbons for the Adsorption of H2S and Mercaptans. *Preprints of Papers-American Chemical Society Division Fuel Chemistry, 41*, 389-393.

Borah, L., Goswami, M. and Phukan, P. (2015). Adsorption of methylene blue and eosin yellow using porous carbon prepared from tea waste: adsorption equilibrium, kinetics and thermodynamics study. *Journal of Environmental Chemical Engineering*, *3*(2), 1018-1028.

Bradley, N. (2007). *The response surface methodology*. Master of Science. Indiana University South Bend.

Brennan, J.K., Thomson, K.T. and Gubbins, K.E. (2002). Adsorption of water in activated carbons: effect of pore blocking and connectivity. *Langmuir*, *18*, 5438-5447.

Bulut, E., Ozacar, M. and Sengil, İ. A. (2008). Adsorption of Malachite Green onto Bentonite: Equilibrium and Kinetic Studies and Process Design. *Microporous and Mesoporous Materials, 115*(3), 234-246.

Burchmore, S. and Wilkinson, M. (1993). *Proposed environmental quality standards for malachite green in water (DWE 9026).* UK Department of the Environment, Transport, and the Regions Report No. 3167/2, prepared by the Water Research Centre, Marlow, Buckinghamshire, England.

Burchmore, S. and Wilkinson, M. (1993). *Proposed Environmental Quality Standards for Malachite Green in Water (DWE 9026). Department of the Environment, Report no. 3167/2*. Marlow, Buckinghamshire, UK: Water Research Center.

Burkinshaw, S. M. (1995). *Chemical Principles of Synthetic Fibre Dyeing*. Glasgow, Scotland: Blackie Academic & Professional.

Burkinshaw, S. M. and Kabambe, O. (2011). Attempts to reduce water and chemical usage in the removal of bifunctional reactive dyes from cotton: part 2 bis (vinyl sulfone), aminochlorotriazine/vinyl sulfone and bis (aminochlorotriazine/vinyl sulfone) dyes. *Dyes and Pigments, 88*(2), 220-229.

Cai, Z., Deng, X., Wang, Q., Lai, J., Xie, H., Chen, Y., Huang, B. and Lin, G. (2019). Core-shell granular activated carbon and its adsorption of trypan blue. *Journal of Cleaner Production*, 118496.

Calvete, T., Lima, E. C., Cardoso, N. F., Dias, S. L. and Pavan, F. A. (2009). Application of Carbon Adsorbents Prepared from the Brazilian Pine-fruit-shell for the Removal of Procion Red MX 3B from Aqueous Solution—Kinetic, Equilibrium, and Thermodynamic Studies. *Chemical Engineering Journal, 155*(3), 627-636.

Cao, Y., Wang, K., Wang, X., Gu, Z., Fan, Q., Gibbons, W., Hoefelmeyer, J. D., Kharel, P. R. and Shrestha, M. (2016). Hierarchical porous activated carbon for supercapacitor derived from corn stalk core by potassium hydroxide activation. *Electrochimica Acta, 212*, 839-847.

Carrott, P. J. M., Carrott, M. R. and Roberts, R. A. (1991). Physical Adsorption of Gases by Microporous Carbons. *Colloids and Surfaces, 58*(4), 385-400.

Cavazzuti, F. (2013). Luigi Spaventa in Consob (Luigi Spaventa at Consob). *Moneta e Credito, 66*(263), 299-335.

Chakraborty, J. N. (2014). *Fundamentals and Practices in Colouration of Textiles*. (2nd Ed.). New Delhi, India:Woodhead Publishing Pvt. Ltd.

Chang, C. F., Yang, C. H., Shu, Y. O., Chen, T. I., Shu, M. S. and Liao, I. C. (2001). Effects of Temperature, Salinity and Chemical Drugs on the in Vitro Propagation of the Dinoflagellate Parasite, Amylodinium ocellatum. *Asian Fish Society, 1*, 31-39.

Chatwal, G. R. (2009). *Synthetic Dyes*. Mumbai: Himalaya Publishing House

Chem-Supply Pty Ltd. (2019). *Phosphoric Acid* [Material Safety Data Sheet]. Bedford St, Gillman, Australia.

Chen, G. and Liu, M. (2011). Adsorption of l-lysine from Aqueous Solution by Spherical Lignin Beads: Kinetics and Equilibrium Studies. *BioResources, 7*(1), 298-314.

Chen, N., Zhang, Z., Feng, C., Li, M., Chen, R. and Sugiura, N. (2011). Investigations on the batch and fixed-bed column performance of fluoride adsorption by Kanuma mud. *Desalination*, *268*(1-3), 76-82.

Chiang, H. L. and Chiang, P. (2000). Physicochemical Characteristics of Ozonation Activated Carbon. In *Adsorption Science and Technology: Proceedings of the Second Pacific Basin Conference on Adsorption Science and Technology.* (pp. 135-139). Australia: World Scientific.

Chieng, H. I., Zehra, T., Lim, L. B., Priyantha, N., and Tennakoon, D. T. B. (2014). Sorption characteristics of peat of Brunei Darussalam IV: equilibrium, thermodynamics and kinetics of adsorption of methylene blue and malachite green dyes from aqueous solution. *Environmental earth sciences, 72*(7), 2263-2277.

Chowdhury, S., Mishra, R., Saha, P. and Kushwaha, P. (2011). Adsorption Thermodynamics, Kinetics and Isosteric Heat of Adsorption of Malachite Green onto Chemically Modified Rice Husk. *Desalination, 265*(1), 159-168.

Chowdhury, S., Yasin, M., Uddin, M. T., and Islam, M. A. (2016). Batch and Continuous (fixed bed column) Adsorption of Methylene Blue by Rubber Leaf Powder. *International Journal of Integrated Sciences & Technology, 2*, 24-28.

Clark, R. M. (1987). Evaluating the cost and performance of field-scale granular activated carbon systems. *Environmental Science & Technology, 21*(6), 573-580.

Collins, J. C., Zain, M. F. H. and Dek, F. S. (2006). Treatment of Landfill Leachate in Kayumadang, Sabah: Textural and Physical Characterization. *Malaysia Journal of Analytical Science, 10*(1), 1-6.

Cornell, J. A. (1984). Volume 8: *How to Apply Response Surface Methodology*. (Revised Edition). Milwaukee, Wisconsin American Society for Quality Control.

Crhribi, A. and Chlendi, M. (2011). Modeling of fixed bed adsorption: application to the adsorption of an organic dye. *Asian Journal of Textile*, *1*, 161-171.

Culp, S. J. and Beland, F. A. (1996). Malachite Green: A Toxicological Review. *International Journal of Toxicology, 15*(3), 219-238.

Dąbrowski, A. (2001). Adsorption—from Theory to Practice. *Advances in Colloid and Interface Science, 93*(1), 135-224.

Dada, A. O., Olalekan, A. P., Olatunya, A. M. and Dada, O. (2012). Langmuir, Freundlich, Temkin and Dubinin–Radushkevich isotherms studies of equilibrium sorption of Zn^{2+} unto phosphoric acid modified rice husk. *IOSR Journal of Applied Chemistry*, *3*(1), 38-45.

Dahri, M. K., Kooh, M. R. R. and Lim, L. B. (2014). Water Remediation using Low Cost Adsorbent Walnut Shell for Removal of Malachite Green: Equilibrium, Kinetics, Thermodynamic and Regeneration Studies. *Journal of Environmental Chemical Engineering, 2*(3), 1434-1444.

Daneshvar, N., Ayazloo, M., Khataee, A. R. and Pourhassan, M. (2007). Biological Decolorization of Dye Solution Containing Malachite Green by Microalgae Cosmarium sp. *Bioresource Technology, 98*(6), 1176-1182.

Das, P., Das, P., and Datta, S. (2016). Continuous biosorption of Malachite Green by Ananus comosus (pineapple) leaf powder in a fixed bed reactor: experimental, breakthrough time and mathematical modeling. *Desalination and Water Treatment, 57*(53), 25842-25847.

Demirbas, A. (2009). Agricultural based activated carbons for the removal of dyes from aqueous solutions: a review. *Journal of hazardous materials, 167*(1), 1-9.

Deniz, F. (2016). A Novel Eco-Biosorbent for Decontamination of Hazardous Dye from Aqueous Medium. *Journal of Polymers and the Environment*, 1-9.

Department of Environment (2005). *Environmental Quality (Scheduled Wastes) Regulations*. Malaysia, P.U.(A) 294.

Department of Environment (2009). *Environmental Quality Report (Industrial Effluent) Regulations*. Malaysia, P.U. (A) 434.

Derbyshier, F., Jagtoyen, M. and Thwaites, M. (1995). Porosity in Carbons. In Patrick, J. W. (Ed.). *Porosity in Carbons: Characterization and Applications*. (pp. 227-232). London: Edward Arnold.

Dhanasekaran, P., Sai, P. S., and Gnanasekar, K. I. (2017). Fixed bed adsorption of fluoride by Artocarpus hirsutus based adsorbent. *Journal of Fluorine Chemistry, 195*, 37-46.

Dichiara, A. B., Weinstein, S. J. and Rogers, R. E. (2015). On the choice of batch or fixed bed adsorption processes for wastewater treatment. *Industrial & Engineering Chemistry Research*, *54*(34), 8579-8586.

Dinesh, S. (2011). *Development and characterization of pellet activated carbon from new precursor*. Bachelor of Technology, National Institute of Technology, Rourkela, India.

El-Khaiary, M. I. and Malash, G. F. (2011). Common data analysis errors in batch adsorption studies. *Hydrometallurgy*, *105*(3-4), 314-320.

Elsayed, A., Mahmoud, S., Al-Dadah, R., Bowen, J. and Kaialy, W. (2014). Experimental and numerical investigation of the effect of pellet size on the adsorption characteristics of activated carbon/ethanol. *Energy Procedia*, *61*, 2327-2330.

Feng, J., Sun, J. and Yan, P. (2018). The influence of ground fly ash on cement hydration and mechanical property of mortar. *Advances in Civil Engineering*, 1-7.

Ferraz, A. I., Tavares, M. T., Teixeira, J. A. (2005) Sorption of Cr(III) From Aqueous Solutions By Spent Brewery Grain. Proceedings of the 9th international chemical engineering conference—CHEMPOR 2005. Coimbra, Portugal.

Ferreira, C. I., Calisto, V., Otero, M., Nadais, H., and Esteves, V. I. (2017). Fixed-bed adsorption of Tricaine Methanesulfonate onto pyrolysed paper mill sludge. *Aquacultural Engineering, 77,* 53-60.

Fontana, F. (1777). Andere Literature Über Adsorption Von Gasen An Der Oberfläche Fester Körper Ist Diese. (German) *Memorie di Matematica e di Fisica della Società Italiana delle Scienze, 1*, 679-692.

Foo, K. Y. and Hameed, B. H. (2010). Insights into the Modeling of Adsorption Isotherm Systems. *Chemical Engineering Journal, 156,* 2-10.

Foo, K. Y., Lee, L. K. and Hameed, B. H. (2013). Preparation of tamarind fruit seed activated carbon by microwave heating for the adsorptive treatment of landfill leachate: a laboratory column evaluation. *Bioresource technology*, *133*, 599-605.

Franssen, M. C. R., Kircher, M., Wohlgemuth, R. (2010) Industrial Biotechnology in the chemical and Pharmaceutical Industries. In: Soetaert, W. and Vandamme, E. J. (Eds.). *Industrial Biotechnology Sustainable Growth and Economic Success.* Weinheim, Germany: Wiley-VCH Verlag GmbH & Co. KGaA.

Freeman, H. S., and Peters, A. T. (2000). *Colorants for Non-textile Applications*. Amsterdam, The Netherlands: Elsevier.

Freeman, H. S., Hinks, D. and Esancy, J. (1996). *Genotoxicity of Azo Dyes: Bases and Implications*. In Peters, A. T. and Freeman, H. S. (Eds.). *Physico-Chemical Principles of Color Chemistry* (pp. 254-292). London, U.K: Chapman & Hall.

Freundlich, H. M. F. (1906). Over the Adsorption in Solution. *Journal of Physical Chemistry, 57*(385), 385-470.

Gabaldon, C., Marzal, P., Seco, A. and Gonzalez, J. A. (2000). Cadmium and Copper Removal by a Granular Activated Carbon in Laboratory Column Systems. *Separation Science and Technology, 35*(7), 1039-1053.

Garba, Z. N. and Rahim, A. A. (2014). Process Optimization of K2C2O4 Activated Carbon from Prosopis africana Seed Hulls Using Response Surface Methodology. *Journal of Analytical and Applied Pyrolysis, 107,* 306-312.

Garba, Z. N., Bello, I., Galadima, A. and Lawal, A. Y. (2016). Optimization of adsorption conditions using central composite design for the removal of copper (II) and lead (II) by defatted papaya seed. *Karbala International Journal of Modern Science*, *2*(1), 20-28.

GEPEA Université de Nantes (2009). D15.2 Report of the AC adsorption technology for aromatic compounds Removal of industrial wastewaters using AC from WWTP sludge. *Removals*, 2-14.

Gereffi, G. (2002). Outsourcing and Changing Patterns of International Competition in the Apparel Commodity Chain. *Responding to Globalization: Societies, Groups and Individuals*. 4-7 April. Boulder, Colorado.

Ghaly, A. E., Ananthashankar, R., Alhattab, M. and Ramakrishnan, V. V. (2014). Production, Characterization and Treatment of Textile Effluents: A Critical Review. *Journal of Chemical Engineering & Process Technology, 5*(1), 182-199.

Gimbert, F., Morin-Crini, N., Renault, F., Badut, P. M. and Crini, G. (2008). Adsorption Isotherm Models for Dye Removal by Cationized Starch-based Material in a Single Component System: Error Analysis. *Journal of Hazardous Materials, 157*, 34-46.

González, P.G. and Pliego-Cuervo, Y.B. (2014). Adsorption of Cd(II), Hg(II) and Zn(II) from Aqueous Solution Using Mesoporous Activated Carbon Produced from Bambusa Vulgaris Striata. *Chemical Engineering Research and Design*. Unpublished.

Gopal, N., Asaithambi, M., Sivakumar, P., and Sivakumar, V. (2016). Continuous fixed bed adsorption studies of Rhodamine-B dye using polymer bound adsorbent. *Indian Journal of Chemical Technology, 23,* 53-58.

Gouranchat, C. (2000). *Malachite Green in Fish Culture (State of the Art and Perspectives). Bibliographic Studies*. Nantes, France: École Nationale Vétérinaire de Toulouse (ENVT).

Grobelak, A. and Jaskulak, M. (2019). Sludge multifunctions in a phytobiome—Forest and plantation application including microbial aspects. In *Industrial and Municipal Sludge* (pp. 323-336). Butterworth-Heinemann.

Guo, H., Chen, J., Weng, W. and Li, S. (2011). Hydrothermal Synthesis of C-Doped $Zn_3(OH)_2V_2O_7$ Nanorods and Their Photocatalytic Properties Under Visible Light Illumination. *Applied Surface Science, 257*(9), 3920-3923.

Guo, J. and Lua, A. C. (2002). Textural and chemical characterizations of adsorbent prepared from palm shell by potassium hydroxide impregnation at different stages. *Journal of Colloid and Interface Science*, *254*(2), 227-233.

Guo, S., Peng, J., Li, W., Yang, K., Zhang, L., Zhang, S. and Xia, H. (2009). Effects of CO2 activation on porous structures of coconut shell-based activated carbons. *Applied Surface Science*, *255*(20), 8443-8449.

Guo, Z., Bian, X., Zhang, J., Liu, H., Cheng, C., Zhang, C. and Wang, J. (2014). Activated Carbons with well-developed microporosity prepared from Phragmites australis by potassium silicate activation. *Journal of the Taiwan Institute of Chemical Engineers, 45,* 2801-2804.

Gupta, V. K. and Suhas (2009). Application of Low-Cost Adsorbents for Dye Removal - A Review. *Journal of Environmental Management, 90,* 2313-2342.

Gupta, V. K., Tyagi, I., Agarwal, S., Singh, R., Chaudhary, M., Harit, A., and Kushwaha, S. (2016). Column operation studies for the removal of dyes and phenols using a low cost adsorbent. *Global Journal of Environmental Science and Management, 2*(1), 1-10.

Gurten, I. I., Ozmak, M., Yagmur, E. and Aktas, Z. (2012). Preparation and characterization of Activated Carbon from Waste Tea Using K_2CO_3. *Biomass and Bioenergy, 37,* 73-81.

Haghseresht, F. and Lu, G. Q. (1998). Adsorption Characteristics of Phenolic Compounds onto Coal-Reject-Derived Adsorbents. *Energy Fuels, 12*(6), 1100-1107.

Hameed, B. H. (2009). Evaluation of Papaya Seeds as a Novel Non-conventional Low-cost Adsorbent for Removal of Methylene Blue. *Journal of Hazardous Materials, 162*(2), 939-944.

Hameed, B. H. and El-Khaiary, M. I. (2008). Equilibrium, kinetics and mechanism of malachite green adsorption on activated carbon prepared from bamboo by K2CO3 activation and subsequent gasification with CO_2. *Journal of Hazardous Materials*, *157*(2-3), 344-351.

Hameed, B. H., Tan, I. A. W. and Ahmad, A. L. (2008). Adsorption Isotherm, Kinetics Modeling and Mechanism of 2,4,6-trichlorophenol on Coconut Husk-Based Activated Carbon. *Chemical Engineering Journal, 144*, 235-244.

Han, R., Wang, Y., Zhao, X., Wang, Y., Xie, F., Cheng, J. and Tang, M. (2009). Adsorption of methylene blue by phoenix tree leaf powder in a fixed-bed column: experiments and prediction of breakthrough curves. *Desalination*, *245*(1-3), 284-297.

Hanum, F., Yuan, L. C., Kamahara, H., Aziz, H. A., Atsuta, Y., Yamada, T. and Daimon, H. (2019). Treatment of Sewage Sludge using Anaerobic Digestion in Malaysia: Current State and Challenges. *Frontiers in Energy Research*, *7*, 19.

Hashim, N. H., Bakar, A. A. and Awang, Z. (2019). Characterizing the Quality of Domestic and Textile Industrial Wastewater as a Preliminary Investigation towards Treatment Suitability. *Journal of Applied Chemistry and Natural Resources*. 1(1), 1-6.

Hemmati, F., Norouzbeigi, R., Sarbisheh, F., and Shayesteh, H. (2016). Malachite green removal using modified sphagnum peat moss as a low-cost biosorbent: Kinetic, equilibrium and thermodynamic studies. *Journal of the Taiwan Institute of Chemical Engineers, 58,* 482-489.

Hena, S. (2010). Removal of chromium hexavalent Ion from Aqueous Solutions Using Biopolymer Chitosan Coated With Poly-3-methyl Thiophene Polymer. *Journal of Hazardous Materials, 181*(1), 474-479.

Henseler, J., Ringle, C. M. and Sinkovics, R. R. (2009). The use of partial least squares path modeling in international marketing. In *New challenges to international marketing* (pp. 277-319). Emerald Group Publishing Limited.

Hidayah, N., Abu Bakar, F., Mahyudin, N. A., Faridah, S., Nur-Azura, M. S. and Zaman, M. Z. (2013). Detection of malachite green and leuco-malachite green in fishery industry. *International Food Research Journal*, *20*(4), 1511-1519.

Hirunpraditkoon, S., Tunthong, N., Ruangchai, A. and Nuithitikul, K. (2011). Adsorption Capacities of Activated Carbons Prepared from Bamboo by KOH Activation. *World Academy of Science, Engineering and Technology, 5*(6), 591-595.

Ho (a), Y. S. and McKay, G. (1998). The Kinetics of Sorption of Basic Dyes from Aqueous Solution by Sphagnum Moss Peat. *The Canadian Journal of Chemical Engineering, 76*(4), 822-827.

Ho, Y. S. and McKay, G. (2002). Application of Kinetic Models to the Sorption of Copper (II) on to Peat. *Adsorption Science and Technology, 20*(8), 797-815.

Ho, Y. S., Porter, J. F. and Mckay, G. (2002). Equilibrium Isotherm Studies for the Sorption of Divalent Metal Ions onto Peat: Copper, Nickel and Lead Single Component Systems. *Water, Air and Soil Pollution, 141*, 1-33.

Hoffman, G. L. and Meyer, F. P. (1974). *Parasites of Freshwater Fishes. A review of Their Control and Treatment.* New Jersey: TFH Publications.

Holme, I. (2000). Coloration of Technical Textiles. In Horrocks, A. R. and Anand, S. C. (Ed.). *Handbook of Technical Textiles*. (pp.187-203). England:Woodhead Publishing Limited.

Horsfall Jnr, M. and Spiff, A. I. (2005). Effects of temperature on the sorption of Pb2+ and Cd2+ from aqueous solution by Caladium bicolor (Wild Cocoyam) biomass. *Electronic Journal of Biotechnology*, *8*(2), 43-50.

Hu, Z. and Srinivasan, M. P. (2001). Mesoporous High-Surface-Area Activated Carbon. *Microporous and Mesoporous Materials, 43*(3), 267-275.

Huang, H. and Zhang, G. (2015). Adsorption of Rhodamine B onto a yellow–brown soil: Kinetics, thermodynamics, and role of soil organic matter. *Environmental Progress & Sustainable Energy*, *34*(5), 1396-1403.

Hunger, K. (2003). *Industrial Dyes: Chemistry, Properties, Applications*. Weinheim, Germany: Wiley-VCH Verlag GmbH & Co. KGaA.

Hunsom, M. and Autthanit, C. (2013). Adsoprtive Purification of Crude Glycerol by Sewage Sludge-derived Activated Carbon Prepared by Chemical Activation with H_3PO_4, K_2CO_3 and KOH. *Chemical Engineering Journal, 229*, 334-343.

Hutchins, R. A. (1973). New method simplifies design of activated-carbon systems. *Chemical Engineering, 80*(19), 133-138.

Idris, A., Hashim, R., Abdul Rahman, R., Ahmad, W. A., Ibrahim, Z., Abdul Razak, P. R., Mohd Zin, H. and Bakar, I. (2007). Application of Bioremediation Process for Textile Wastewater Treatment Using Pilot Plant. *International Journal of Engineering and Technology, 4*(2), 228-234.

IndahWater Konsortium Sdn Bhd (2010). *A Potty History of Sewage Sludge and it Treatment*. IndahWater Konsortium Sdn Bhd.

Iqbal, M. (2008). *Textile Dyes*. Karachi, Pakistan: Rehbar Publisher.

Islam, M. S., Ang, B. C., Gharehkhani, S. and Afifi, A. B. M. (2016). Adsorption capability of activated carbon synthesized from coconut shell. *Carbon Letters, 20*(1), 1-9.

Itodo, A. U. and Itodo, H. U. (2010). Sorption Energies Estimation Using Dubinin-Radushkevich and Temkin Adsorption Isotherms. Life Science *Journal-Acta Zhengzhou University Overseas Edition, 7*(4), 31-39.

Itodo, A. U., Abdulrahman, F. W., Hassan, L. G., Maigandi, S. A. and Itodo, H. U. (2010). Intraparticle Diffusion and Intraparticulate Diffusivities of Herbicide on Derived Activated Carbon. *Researcher, 2*(2), 74-86.

Jerold, M., Joseph, D., Patra, N., and Sivasubramanian, V. (2016). Fixed-bed column studies for the removal of hazardous malachite green dye from aqueous solution using novel nano zerovalent iron algal biocomposite. *Nanotechnology for Environmental Engineering*, *1*(1), 8-17.

Jibril, M. (2015). *Preparation and surface modification of activated carbon from coconut shells for benzene and toluene adsorption from water*. PhD Dissertation, Universiti Teknologi Malaysia.

Joseph, C. G., Bono, A., Krishnaiah, D., Ling, C. Y. and Ban, N. C. (2009). Morphology and sorption kinetic studies of L-type activated carbons prepared from oil palm shells by $ZnCl_2$ and H_3PO_4 activation. *Journal of Applied Sciences*, *9*(17), 3131-3135.

Joshi, M., Bansal, R. and Purwar, R. (2004). Colour Removal from Textile Effluents. *Indian Journal of Fibre and Textile Research, 29*(2), 239-259.

Joshi, R. R. (2015). Optimization of Conditions for the Preparation of Activated Carbon from Lapsi (Choerospondias axillaris) Seed Stone Using $ZnCl_2$. *Journal of the Institute of Engineering*, *11*(1), 128-139.

Jossens, L., Prausnitz, J. M., Fritz, W., Schlünder, E. U. and Myers, A. L. (1978). Thermodynamics of Multi-solute Adsorption from Dilute Aqueous Solutions. *Chemical Engineering Science, 33*(8), 1097-1106.

Kacan, E. (2016). Optimum BET surface areas for activated carbon produced from textile sewage sludges and its application as dye removal. *Journal of environmental management*, *166*, 116-123.

Kacan, E. and Kutahyali, C. (2012). Adsorption of Strontium Aqueous Solution Using Activated Carbon Produced from Textile Sewage Sludge. *Journal of Analytical and Applied Pyrolysis, 97*, 149-157.

Kadir, M. A. and Mohd, H. D. (1998). The management of municipal wastewater sludge in Malaysia. *Tropics, 28*, 109–120.

Kalavathy, M. H., Karthikeyan, T., Rajgopal, S. and Miranda, L. R. (2005). Kinetic and Isotherm Studies of Cu (II) Adsorption onto H_3PO_4-Activated Rubber Wood Sawdust. *Journal of Colloid and Interface Science, 292*(2), 354-362.

Kant, R. (2012). Textile Dyeing Industry an Environmental Hazard. *Natural Science, 4*(1), 22-26.

Kargi, F. and Ozmihci, S. (2004). Biosorption Performance of Powdered Activated Sludge for Removal of Differential Dyestuffs. *Enzyme and Microbial Technology*, *35*, 267-271.

Karthikeyan, S., Sivakumar, B. and Sivakumar, N. (2010). Film and Pore Diffusion Modeling for Adsorption of Reactive Red 2 from Aqueous Solution onto Activated Carbon Preparedfrom Bio-Diesel Industrial Waste. *Journal of Chemistry, 7*(S1), S175-S184.

Karunarathne, H. D. S. S. and Amarasinghe, B. M. W. P. K. (2013). Fixed bed adsorption column studies for the removal of aqueous phenol from activated carbon prepared from sugarcane bagasse. *Energy Procedia*, *34*, 83-90.

Katesa, J., Junpiromand, S. and Tangsathitkulchai, C. (2010). Effect of Carbonization Temperature on Properties of Char and Activated Carbon from Coconut Shell. *Suranaree Journal of Science and Technology*, *20*(4), 269-278.

Kaçan, E. and Kütahyali, C. (2012). Adsorption of Strontium Aqueous Solution Using Activated Carbon Produced from Textile Sewage Sludge. *Journal of Analytical and Applied Pyrolysis, 97*, 149-157.

Keane, J. and te Velde, D. W. (2008). *The Role of Textile and Clothing Industries in Growth and Development Strategies.* Investment and Growth Programme, Overseas Development Institute.

Kemmer, F. N., Mattix, R. D. and Robertson, R. S. (1971). *U.S. Patent No. 3, 619, 420.* Washington, DC: U.S. Patent and Trademark Office.

Khalil, H. P. S. A., Firoozian, P., Bakare, I. O., Akil, H. M. and Noor, A. M. (2010). Exploring Biomass Based Carbon Black as Filler in Epoxy Composites: Flexural and Thermal Properties. *Material Design, 31*, 3419-3425.

Khan, A. R., Riazi, M. R. and Al-Roomi, Y. A. (2000). A Thermodynamic Model for Liquid Adsorption Isotherms. *Separation Purification Technology, 18,* 237-250.

Khan, S. and Malik, A. (2014). Environmental and Health Effects of Textile Industry Wastewater. In Malik, A., Grohmann, E. And Akhtar, R. (Eds.*). Environmental Deterioration and Human Health*. (pp. 55-71). Netherlands: Springer.

Khan, T. A., Sharma, S. and Ali, I. (2011). Adsorption of Rhodamine B dye from aqueous solution onto acid activated mango (Magnifera indica) leaf powder: equilibrium, kinetic and thermodynamic studies. *Journal of Toxicology and Environmental Health Sciences, 3*(10), 286-297.

Khehra, M. S., Saini, H. S., Sharma, D. K., Chadha, B. S. and Chimni, S. S. (2006). Biodegradation of Azo Dye CI Acid Red 88 by an Anoxic–Aerobic Sequential Bioreactor. *Dyes and Pigments*, *70*(1), 1-7.

Kibami, D., Pongener, C., Rao, K. S. and Sinha, D. (2014). Preparation and Characterization of Activated Carbon from Fagopyrum esculentum Moench by HNO_3 and H_3PO_4 Chemical Activation. *Der Chemica Sinica*, *5*(4), 46-55.

Kiernan, J. A. (2001). Classification and Naming of Dyes, Stains and Fluorochromes. *Biotechnic & Histochemistry*, *76*(5-6), 261-278.

Kiliç, M., Apaydin-Varol, E. and Pütün, A. E. (2012). Preparation and Surface Characterization of Activated Carbons from Euphorbia rigida by Chemical Activation with $ZnCl_2$, K_2CO_3, NaOH and H_3PO_4. *Applied Surface Science, 261*, 247-254.

Kong, J., Yue, Q., Gao, B., Li, Q., Wang, Y., Ngo, H. H. and Guo, W. (2014). Porous Structure and Adsorptive Properties of Hide Waste Activated Carbons Prepared via Potassium Silicate Activation. *Journal of Analytical and Applied Pyrolysis, 109*, 311-314.

Kualiti Alam Sdn. Bhd. (2016). *Scheduled waste transportation and treatment agreement*. Available at: https://cwc.kualitialam.com/CWC/Registration.aspx (Accessed: 7 August 2019).

Kuila, U. and Prasad, M. (2013). Specific surface area and pore-size distribution in clays and shales. *Geophysical Prospecting*, *61*(2), 341-362.

Kumar, K. V. (2006). Comparative Analysis of Linear and Non-Linear Method of Estimating the Sorption Isotherm Parameters for Malachite Green onto Activated Carbon. *Journal of Hazardous Materials, 136*(2), 197-202.

Kushwaha, A. K., Gupta, N. and Chattopadhyaya, M. C. (2014). Removal of Cationic Methylene Blue and Malachite Green Dyes from Aqueous Solution by Waste Materials of Daucus carota. *Journal of Saudi Chemical Society, 18*(3), 200-207.

Kwiatkowski, J. F. (2011). *Activated Carbon: Classifications, Properties and Applications*. New York, USA: Nova Science Publishers.

Laksaci, H., Khelifi, A., Trari, M., and Addoun, A. (2017). Synthesis and characterization of microporous activated carbon from coffee grounds using potassium hydroxides. *Journal of Cleaner Production, 147*, 254-262.

Langmuir, I. (1916). The Constitution and Fundamental Properties of Solids and Liquids. *Journal of the American Chemical Society, 38*(11), 2221-2295.

Lee, C. G., Kim, J. H., Kang, J. K., Kim, S. B., Park, S. J., Lee, S. H., and Choi, J. W. (2015). Comparative analysis of fixed-bed sorption models using phosphate breakthrough curves in slag filter media. *Desalination and Water Treatment, 55*(7), 1795-1805.

Lee, L. Z. and Zaini, M. A. A. (2016). Adsorption properties of cationic rhodamine B dye onto metals chloride-activated castor bean residue carbons. *Water Science and Technology*, *75*(4), 864-880.

Leon, Y. C. L., Solar, J. M., Calemma, V. and Radovic, L. R. (1992). Evidence for the Protonation of Basal Plane Sites on Carbon. *Carbon, 30*(5), 797-811.

Lester, J. N., Sterritt, R. M., Kirk, P. W. W. (1983). Significance and behaviour of heavy metals in waste water treatment processes II. Sludge treatment and disposal. *Sci. Total Environ*., *30*, 45-83.

Li, D., Tang, R., Tian, Y., Qiao, Y., and Li, J. (2014c). Preparation of highly porous binderless active carbon monoliths from waste aspen sawdust. *BioResources, 9*(1), 1246-1254.

Li, D., Tian, Y., and Qiao, Y. (2014b). Forming Active Carbon Monoliths from H_3PO_4-loaded Sawdust with Addition of Peanut Shell Char. *BioResources, 9*(3), 4981-4992.

Li, D., Tian, Y., Qiao, Y., and Wen, L. (2014a). Conversion of powdered active carbon into monoliths without reducing specific surface area using H_3PO_4-impregnated waste sawdust. *Materials Letters, 125*, 175-178.

Li, X. F., Xu, Q., Fu, Y. and Guo, Q. X. (2014d). Preparation and Characterization of Activated Carbon from Kraft Lignin via KOH Activation. *Environmental Progress & Sustainable Energy, 33*(2), 519-526.

Lillo-Rodenas, M. A., Cazorla-Amoros, D., and Linares-Solano, A. (2003). Understanding Chemical Reactions Between Carbons and NaOH and KOH An Insight Into the Chemical Activation Mechanism. *Carbon, 41*, 267-275.

Liu, D. and Sun, D. (2011). Simulation of indigo carmine dye adsorption on polymer doped sawdust in fixed-bed systems. *Desalination and Water Treatment*, *27*(1-3), 285-293.

Liu, L., Wang, L., Yin, L., Song, W., Yu, J. and Liu, Y. (2014). Effects of Different Solvents on the Surface Acidic Oxygen-containing Functional Groups on Xanthoceras sorbifolia Shell. *BioResources, 9*(2), 2248-2258.

Liu, R. L., Liu, Y., Zhou, X. Y., Zhang, Z. Q., Zhang, J. and Dang, F. Q. (2014). Biomass-derived highly porous functional carbon fabricated by using a free-standing template for efficient removal of methylene blue. *Bioresource technology*, *154*, 138-147.

Liu, S. (2015). Cooperative adsorption on solid surfaces. *Journal of Colloid and Interface Science, 450*, 224-238.

Lozano-Castello, D., Cazorla-Amorós, D., Linares-Solano, A., and Quinn, D. F. (2002). Activated carbon monoliths for methane storage: influence of binder. *Carbon*, *40*(15), 2817-2825.

Mahapatra, K., Ramteke, D. S. and Paliwal L. J. (2012). Production of Activated Carbon from Sludge of Food Processing Industry Under Controlled Pyrolysis and Its Application for Methylene Blue Removal. *Journal of Analytical and Applied Pyrolysis, 95*, 79-86.

Maksin, D. D., Kljajević, S. O., Đolić, M. B., Marković, J. P., Ekmeščić, B. M., Onjia, A. E. and Nastasović, A. B. (2012). Kinetic Modeling of Heavy Metal Sorption by Vinyl Pyridine Based Copolymer. *Hemijska Industrija, 66*(6), 795-804

Malaysian Investment Development Authority (MIDA) (2012). *Malaysia –Investment Performance 2011*, MIDA, Kuala Lumpur, Malaysia.

Malik, R., Ramteke, D. S. and Wate, S. R. (2007). Adsorption of Malachite Green on Groundnut Shell Waste Based Powdered Activated Carbon. *Waste Management, 27*(9), 1129-1138.

Manikandan, B., Ramamurthi, V., Karthikeyan, R. and Sundararaman, T. R. (2009). Biobleaching of textile dye effluent using mixed culture through an immobilized packed bed bioreactor (IPBBR). *Mod Appl Sci*, *3*(5), 131-135.

Manocha, S. M. (2003). Porous Carbons. *Sadhana, 28*(1-2), 335-348.

Markovska, L., Meshko, V., and Noveski, V. (2001). Adsorption of basic dyes in a fixed bed column. *Korean Journal of Chemical Engineering, 18*(2), 190-195.

Marsh, H. and Rodríguez-Reinoso, F. (2006). *Activated Carbon*. Oxford, U.K.: Elsevier.

Martin, M. J., Artola, A., Balaguer, M. D. and Rigola, M. (2002). Towards Waste Minimization in WWTP: Activated Carbon from Biological Sludge and Its Application in Liquid Phase Adsorption. *Journal of Chemical Technology and Biotechnology, 77*(7), 825-833

Maulina, S. and Iriansyah, M. (2018). Characteristics of activated carbon resulted from pyrolysis of the oil palm fronds powder. *IOP Conference Series: Materials Science and Engineering*, 309(1), 12072.

Mckay, G. (1983). The Adsorption of Dyestuffs from Aqueous Solutions Using Activated Carbon. III. Intraparticle Diffusion Processes. Journal of Chemical Technology and Biotechnology. *Chemical Technology, 33*(4), 196-204.

McKay, G., Otterburn, M. S. and Sweeney, A. G. (1980). The Removal of Color From Effluent Using Various Adsorbents—III. Silica: Rate Processes. *Water Research, 14*(1), 15-20.

Medvidović, N. V., Perić, J. and Trgo, M. (2008). Testing of breakthrough curves for removal of lead ions from aqueous solutions by natural zeolite-clinoptilolite according to the Clark kinetic equation. *Separation Science and Technology*, *43*(4), 944-959.

Medvidović, N. V., Perić, J., and Trgo, M. (2008). Testing of Breakthrough Curves for Removal of Lead Ions from Aqueous Solutions by Natural Zeolite-Clinoptilolite According to the Clark Kinetic Equation. *Separation Science and Technology, 43*(4), 944-959.

Mestre, A. S., Bexiga, A. S., Proença, M., Andrade, M., Pinto, M. L., Matos, I., Fonseca, I. M. and Carvalho, A. P. (2011). Activated Carbons from Sisal Waste by Chemical Activation with K_2CO_3: Kinetics of Paracetamol and Ibuprofen Removal From Aqueous Solution. *Bioresource Technology, 102,* 8253-8260.

Mezohegyi, G., van der Zee, F. P., Font, J., Fortuny, A. and Fabregat, A. (2012). Towards Advanced Aqueous Dye Removal Processes: A Short Review on Versatile Role of Activated Carbon. *Journal of Environmental Management, 102*, 148-164.

Michaels, A. S. (1952). Simplified method of interpreting kinetic data in fixed-bed ion exchange. *Industrial & Engineering Chemistry*, *44*(8), 1922-1930.

Michelson, L. D., Gideon. P. G., Pace, E. G., and Kutal, L. H. (1975). US Department Industry, Office of Water Research and Technology. *Bulletin, No.74*.

Mochizuki, T., Kubota, M., Matsuda, H., and Camacho, L. F. E. (2016). Adsorption behaviors of ammonia and hydrogen sulfide on activated carbon prepared from petroleum coke by KOH chemical activation. *Fuel Processing Technology*. *144*, 164-169.

Mohammadi, M., Hassani, A. J., Mohamed, A. R. and Najafpour, G. D. (2010). Removal of rhodamine B from aqueous solution using palm shell-based activated carbon: adsorption and kinetic studies. *Journal of Chemical & Engineering Data*, *55*(12), 5777-5785.

Monsalvo, V. M., Mohedano, A. F. and Rodriguez, J. J. (2011). Activated Carbons from Sewage Sludge: Application to Aqueous-phase Adsorption of 4-chlorophenol. *Desalination, 277*(1), 377-382.

Moody, V. and Needles, H. L. (2004). *Tufted Carpet: Textile Fibers, Dyes, Finishes and Processes*. Norwich, New York, U.S.A: William Andrew Publishing.

Moore, D. S., Notz, W. and Fligner, M. A. (2013). *The basic practice of statistics*. WH Freeman.

Mudhoo, A. and Beekaroo, D. (2011). *Adsorption of Reactive Red 158 Dye by Chemically Treated Cocos nucifera L. Shell Powder*. Dordrecht, Netherlands: Springer.

Muinde, V. M., Onyari, J. M., Wamalwa, B., Wabomba, J., and Nthumbi, R. M. (2017). Adsorption of Malachite Green from Aqueous Solutions onto Rice Husks: Kinetic and Equilibrium Studies. *Journal of Environmental Protection, 8*(03), 215-230.

Muniandy, L., Adam, F., Mohamed, A. R. and Ng, E. P. (2014). The Synthesis and Characterization of High Purity Mixed Microporous/Mesoporous Activated Carbon from Rice Husk Using Chemical Activation With NaOH and KOH. *Microporous and Mesoporous Materials, 197*, 316-323.

Muñoz, Y., Arriagada, R., Soto-Garrido, G. and García, R. (2003). Phosphoric and boric acid activation of pine sawdust. *Journal of Chemical Technology & Biotechnology: International Research in Process, Environmental & Clean Technology*, *78*(12), 1252-1258.

Muruganandham, M. and Swaminathan, M. (2004). Photochemical Oxidation of Reactive Azo Dye With UV–H2O2 Process. *Dyes and Pigments, 62*(3), 269-275.

Muyibi, S. A., Ambali, A. R. and Eissa, G. S. (2008). The impact of economic development on water pollution: Trends and policy actions in Malaysia. *Water resources management*, *22*(4), 485-508.

Myers, R. H., Montgomery, D. C., and Anderson-Cook, C. M. (2016). *Response surface methodology: process and product optimization using designed experiments.* New Jersey: John Wiley & Sons.

Nair, V., Panigrahy, A. and Vinu, R. (2014). Development of Novel Chitosan-Lignin Composites for Adsorption of Dyes and Metal Ions from Wastewater. *Chemical Engineering Journal*, *254*, 491-502.

Naja, G. and Volesky, B. (2006). Behavior of the mass transfer zone in a biosorption column. *Environmental science & technology*, *40*(12), 3996-4003.

Namasivayam C. and Ranganathan K. (1994). Recycling of 'Waste' Fe(III)/Cr(III) Hydroxide for the Removal of Nickel from Wastewater: Adsorption and Equilibrium Studies. *Waste Management, 14*(8), 709-716.

National Silicates. (2014). *Potassium Silicate* [Material Safety Data Sheet]. Toronto, Canada.

Ncibi, M. C., Ranguin, R., Pintor, M. J., Jeanne-Rose, V., Sillanpää, M. and Gaspard, S. (2014). Preparation and Characterization of Chemically Activated Carbons Derived from Mediterranean *Posidonia oceanica (L.)* Fibres. *Journal of Analytical and Applied Pyrolysis, 109*, 205-214.

Noh J.S. and Schwarz J.A. (1989). Estimation of the Point of Zero Charge of Simple Oxides by Mass Titration. *Journal of Colloidal Interface Science, 130*, 157-164.

Nouri, H. and Ouederni, A. (2013). Modeling of the dynamics adsorption of phenol from an aqueous solution on activated carbon produced from olive stones. *International Journal of Chemical Engineering and Applications*, *4*(4), 254-261.

Nowicki, P., Kazmierczak-Razna, J., and Pietrzak, R. (2016). Physicochemical and adsorption properties of carbonaceous sorbents prepared by activation of tropical fruit skins with potassium carbonate. *Materials & Design, 90,* 579-585.

Nunes, C. A. and Guerreiro, M. C. (2011). Estimation of surface area and pore volume of activated carbons by methylene blue and iodine numbers. *Química Nova*, *34*(3), 472-476.

Nunthaprechachan, T., Pengpanich, S. and Hunsom, M. (2013). Adsorptive Desulfurization of Dibenzothiophene by Sewage Sludge-Derived Activated Carbon. *Chemical Engineering Journal, 228*, 263-271.

Odusote, J. K., Onowuma, S. A., and Fodeke, E. A. (2016). Production of Paperboard Briquette Using Waste Paper and Sawdust. *The Journal of Engineering Research [TJER], 13*(1), 80-88.

Okewale, A. O., Babayemi, K. A. and Olalekan, A. P. (2013). Adsorption Isotherms and Kinetics Models of Starchy Adsorbents on Uptake of Water from Ethanol–Water Systems. *International Journal of Applied Science and Technology, 3*(1), 35-42.

Okman, I., Karagöz, S., Tay, T. and Erdem, M. (2014). Activated Carbons from Grape Seeds by Chemical Activation with Potassium Carbonate and Potassium Hydroxide. *Applied Surface Science*, *293,* 138-142.

Oliveira S., J., Rodrigues Filho, G., da Silva Meireles, C., Ribeiro, S. D., Vieira, J. G., da Silva, C. V. and Cerqueira, D. A. (2012). Thermal Analysis and FTIR Studies of Sewage Sludge Produced in Treatment Plants. The Case of Sludge in the City of Uberlândia-MG, Brazil. *Thermochimica Acta, 528*, 72-75.

Omar, A. H., Muda, K., Majid, Z. A., Affam, A. C., Sapari, N., Olisa, E., Hussein, N., Hashim, N. and Zaidi, N. S. (2018). Development of microbial granule using low strength textile wastewater under influence of static magnetic field. *International Journal of Pure and Applied Mathematics, 118*(24), 1-19.

Omar, W. N. N. W. and Amin, N. A. S. (2011). Optimization of heterogeneous biodiesel production from waste cooking palm oil via response surface methodology. *Biomass and bioenergy*, *35*(3), 1329-1338.

Omar, W. N. N. W. and Amin, N. A. S. (2016). Multi response optimization of oil palm frond pretreatment by ozonolysis. *Industrial Crops and Products*, *85*, 389-402.

Önal, Y., Akmil-Başar, C., Eren, D., Sarıcı-Özdemir, Ç. and Depci, T. (2006). Adsorption kinetics of malachite green onto activated carbon prepared from Tunçbilek lignite. *Journal of Hazardous Materials, 128*(2), 150-157.

Orrego-Romero, A. F., Arbeláez-Pérez, O. F., Bustamante-Londoño, F., and Villa-Holguín, A. L. (2016). Pelletization of catalysts supported on activated carbon. A Case Study: clean synthesis of dimethyl carbonate from methanol and CO_2. *Revista Facultad de Ingeniería Universidad de Antioquia, 78,* 38-47.

Özcan, A. S. and Özcan, A. (2004). Adsorption of Acid Dyes from Aqueous Solutions onto Acid-Activated Bentonite. *Journal of Colloid and Interface Science, 276*(1), 39-46.

Pan, L., Takagi, Y., Matsui, Y., Matsushita, T. and Shirasaki, N. (2017). Micro-milling of spent granular activated carbon for its possible reuse as an adsorbent: Remaining capacity and characteristics. *Water research*, *114*, 50-58.

Pang, Y. L. and Abdullah, A. Z. (2013). Current status of textile industry wastewater management and research progress in Malaysia: a review. *Clean–Soil, Air, Water*, *41*(8), 751-764.

Park, S. H., McClain, S., Tian, Z. R., Suib, S. L. and Karwacki, C. (1997). Surface and Bulk Measurements of Metals Deposited on Activated Carbon. *Chemistry of Materials, 9*(1), 176-183.

Park, S. J. and Jung, W. Y. (2002). Effect of KOH Activation on the Formation of Oxygen Structure in Activated Carbons Synthesized from Polymeric Precursor. *Journal of Colloid and Interface Science, 250*(1), 93-98.

Patel, H. and Vashi, R. T. (2012). Fixed bed column adsorption of ACID Yellow 17 dye onto Tamarind Seed Powder. *The Canadian Journal of Chemical Engineering*, *90*(1), 180-185.

Patil, B. S. and Kulkami, K. S. (2012). Development of High Surface Area Activated Carbon from Waste Material. *International Journal of Advanced Engineering Research and Studies, 1*(2), 109-113.

Pendyal, B., Johns, M. M., Marshall, W. E., Ahmedna, M., and Rao, R. M. (1999). The effect of binders and agricultural by-products on physical and chemical properties of granular activated carbons. *Bioresource Technology, 68*(3), 247-254.

Peng, J., Bi, X. T., Lim, C. J., Peng, H., Kim, C. S., Jia, D., and Zuo, H. (2015a). Sawdust as an effective binder for making torrefied pellets. *Applied Energy*, *157*, 491-498.

Peng, X., Ma, X., and Xu, Z. (2015b). Thermogravimetric analysis of co-combustion between microalgae and textile dyeing sludge. *Bioresource Technology*, *180*, 288-295.

Peng, X., Ma, X., Lin, Y., Guo, Z., Hu, S., Ning, X., Cao, Y., and Zhang, Y. (2015c). Co-pyrolysis between microalgae and textile dyeing sludge by TG–FTIR: kinetics and products. *Energy Conversion and management*, *100,* 391-402.

Philips, D. (1996). Environmentally Friendly, Productive and Reliable: Priorities for Cotton Dyes and Dyeing Processes. *Journal of Society of Dyers and Colourists, 112*, 183-186.

Ponnusamy, S. (2016). Continuous fixed bed adsorption studies of Rhodamine-B dye using polymer bound adsorbent. *Indian Journal of Chemical Technology (IJCT), 23*(1), 53-58.

Prahas, D., Kartika, Y., Indraswati, N. and Ismadji, S. (2008). Activated Carbon from Jackfruit Peel Waste by H_3PO_4 Chemical Activation: Pore Structure and Surface Chemistry Characterization. *Chemical Engineering Journal, 140*, 32-42.

Prasad, R. K. and Srivastava, S. N. (2009). Sorption of Distillery Spent Wash onto Fly Ash: Kinetics and Mass Transfer Studies. *Chemical Engineering Journal, 146*(1), 90-97.

ProChem, Inc. Chemicals Supplier. (2006). *Potassium Formate* [Material Safety Data Sheet]. Rockford, U.S.

Puttamat, S. and Pavarajarn, V. (2016). Adsorption study for removal of Mn (II) ion in aqueous solution by hydrated ferric (III) oxides. *International Journal of Chemical Engineering and Applications*, *7*(4), 239-243.

Qu, W., Yuan, T., Yin, G., Xu, S., Zhang, Q. and Su, H. (2019). Effect of properties of activated carbon on malachite green adsorption. *Fuel, 249*, 45-53.

Rahman, R. A. (1993). Characterisation and Prospects for Biological Treatment of Textile Finishing Wastewater. In Yeoh, B. G., Chee, K. S., Phang, S. M., Isa, Z., Idris, A. and Mohamed, M. (Eds.). *Waste Management in Malaysia: Current Status and Prospects for Bioremediation*. (pp.99-108). Kuala Lumpur, Malaysia: Ministry of Science, Technology and the Environment.

Raissi, S., and Farsani, R. E. (2009). Statistical process optimization through multi-response surface methodology. *World Academy of Science, Engineering and Technology, 51*(46), 267-271.

Ramesh, T., Rajalakshmi, N., and Dhathathreyan, K. S. (2017). Synthesis and characterization of activated carbon from jute fibers for hydrogen storage. *Renewable Energy and Environmental Sustainability, 2,* 4-11.

Raposo, F., De La Rubia, M. A. and Borja, R. (2009). Methylene blue number as useful indicator to evaluate the adsorptive capacity of granular activated carbon in batch mode: Influence of adsorbate/adsorbent mass ratio and particle size. *Journal of hazardous materials*, *165*(1-3), 291-299.

Redlich, O. J. D. L. and Peterson, D. L. (1959). A Useful Adsorption Isotherm. *Journal of Physical Chemistry, 63*(6), 1024-1026.

Reichenberg, D. (1953). Properties of Ion-Exchange Resins in Relation to Their Structure. III. Kinetics of Exchange. *Journal of the American Chemical Society, 75*(3), 589-597.

Rio, S., Faur-Brasquet, C., Le Coq, L., Courcoux, P. and Le Cloirec, P. (2005). Experimental Design Methodology for the Preparation of Carbonaceous Sorbents from Sewage Sludge by Chemical Activation—Application to Air and Water Treatments. *Chemosphere, 58*(4), 423-437.

Rocha, P. D., Franca, A. S. and Oliveira, L. S. (2015). Batch and column studies of phenol adsorption by an activated carbon based on acid treatment of corn cobs. *International Journal of Engineering and Technology*, *7*(6), 459.

Rouquerol, J., Rouquerol, F., Llewellyn, P., Maurin, G. and Sing, K. S. (2013). *Adsorption by Powders and Porous Solids: Principles, Methodology and Applications*. (2nd Ed.). Oxford, UK: Academic Press.

Saadi, Z., Saadi, R. and Fazaeli, R. (2013). Fixed-bed adsorption dynamics of Pb (II) adsorption from aqueous solution using nanostructured γ-alumina. *Journal of Nanostructure in Chemistry*, *3*(1), 48-55.

Saeidi, N., and Lotfollahi, M. N. (2015). A procedure to form powder activated carbon into activated carbon monolith. *The International Journal of Advanced Manufacturing Technology, 81*(5-8), 1281-1288.

Sahu, J. N., Acharya, J. and Meikap, B. C. (2010). Optimization of production conditions for activated carbons from Tamarind wood by zinc chloride using response surface methodology. *Bioresource technology*, *101*(6), 1974-1982.

Samarghandi, M. R., Hadi, M. and McKay, G. (2014). Breakthrough Curve Analysis for Fixed-Bed Adsorption of Azo Dyes Using Novel Pine Cone—Derived Active Carbon. *Adsorption Science & Technology*, *32*(10), 791-806.

Santhi, T., Manonmani, S., Vasantha, V. S. and Chang, Y. T. (2011). A New Alternative Adsorbent for the Removal of Cationic Dyes from Aqueous Solution. Arabian Journal of Chemistry. *Article in Press*.

Sapari, N. (1996). Treatment and reuse of textile wastewater by overland flow. *Desalination, 106*(1-3), 179-182.

Saussure, N. D. (1814). Observations Sur l'Absorption Des Gaz par Différents Corps.(French) *Annalen der Physik, 47,* 113-183.

Sawant, S. Y., Munusamy, K., Somani, R. S., John, M., Newalkar, B. L., and Bajaj, H. C. (2017). Precursor suitability and pilot scale production of super activated carbon for greenhouse gas adsorption and fuel gas storage. *Chemical Engineering Journal, 315*, 415-425.

Sayğılı, H. and Güzel, F. (2018). Usability of activated carbon with well-developed mesoporous structure for the decontamination of malachite green from aquatic environments: kinetic, equilibrium and regeneration studies. *Journal of Porous Materials, 25*(2), 477-488.

Scheele, C. W. (1773). *Chemische Abhandlung von der Luft und dem Feuer*. (German) Uppsala, Sweden: Leipzig.

Schimmel, D., Fagnani, K. C., Santos, J. B., Barros, M. A. S. D. and Silva, E. (2010). Adsorption of turquoise blue QG reactive bye commercial activated carbon in batch reactor: kinetic and equilibrium studies. *Brazilian Journal of Chemical Engineering*, *27*(2), 289-298.

Schnick, R. A. (1988). The Impetus to Register New Therapeutants for Aquaculture. *The Progressive Fish-Culturist, 50*(4), 190-196.

ScienceLab: Chemicals & Laboratory. (2013a). *Potassium Hydroxide* [Material Safety Data Sheet]. Houston, Texas, U.S.

ScienceLab: Chemicals & Laboratory. (2013b). *Potassium Acetate* [Material Safety Data Sheet]. Houston, Texas, U.S.

ScienceLab: Chemicals & Laboratory. (2013c). *Potassium Perchlorate* [Material Safety Data Sheet]. Houston, Texas, U.S.

ScienceLab: Chemicals & Laboratory. (2013d). *Potassium Iodide* [Material Safety Data Sheet]. Houston, Texas, U.S.

Scott, S. A., Dennis, J. S., Davidson, J. F. and Hayhurst, A. N. (2006). Thermogravimetric Measurements of the Kinetics of Pyrolysis of Dried Sewage Sludge. *Fuel, 85*(9), 1248-1253.

Shaikh, M. A. (2009). Water Conservation in Textile Industry. *Pakistan Textile Journal, 11*, 48-51.

Sharma, P. and Das, M. R. (2012). Removal of a cationic dye from aqueous solution using graphene oxide nanosheets: investigation of adsorption parameters. *Journal of Chemical & Engineering Data*, *58*(1), 151-158.

Shen, Z. M., Wu, D., Yang, J., Yuan, T., Wang, W. H. and Jia, J. P. (2006). Methods to Improve Electrochemical Treatment Effect of Dye Wastewater. *Journal of Hazardous Materials, 131*(1), 90-97.

Shin, H. S. and Kim, J. H. (2016). Isotherm, kinetic and thermodynamic characteristics of adsorption of paclitaxel onto Diaion HP-20. *Process Biochemistry*, *51*(7), 917-924.

Shrihari, V., Madhan, S. and Das, A. (2005). Kinetics of Phenol Sorption by Raw Agrowastes. *Applied Sciences, 6*(1), 47-50.

Si, Y., Hu, J., Wang, X., Yang, H., Chen, Y., Shao, J., and Chen, H. (2016). Effect of carboxymethyl cellulose binder on the quality of biomass pellets. *Energy & Fuels, 30*(7), 5799-5808.

Siminiceanu, I., Marchitan, N., Duca, G. and Mereuta, A. (2010). Mathematical Models Based on Thermodynamic Equilibrium and Kinetics of an Ion Exchange Process. *Revista de Chimie, 61*(7), 623-626.

Singh, S. K., Townsend, T. G., Mazyck, D. and Boyer, T. H. (2012). Equilibrium and intra-particle diffusion of stabilized landfill leachate onto micro-and meso-porous activated carbon. *Water research*, *46*(2), 491-499.

Skoog, D. A. and West, D. M. (1980). *Principles of instrumental analysis* (3rd Ed.). Saunders College Publishing: New York.

Smith, K. M., Fowler, G. D., Pullket, S. and Graham, N. J. D. (2009). Sewage Sludge-Based Adsorbents: A Review of Their Production, Properties and Use in Water Treatment Applications. *Water Research, 43*(10), 2569-2594.

Socrates, G. (1995). Infrared Characteristic Group Frequencies, Tables and Charts. *Journal of the American Chemical Society, 117*(5), 1671-1671.

Sohaimi, K. S. A. and Ngadi, N. (2016). Removal of Oil Using Activated Carbon from Textile Sludge Biochars. *Applied Mechanics and Materials, 818*, 237-241.

Sohaimi, K. S. A., Ngadi, N., Mat, H., Inuwa, I. M. and Wong, S. (2017). Synthesis, characterization and application of textile sludge biochars for oil removal. *Journal of environmental chemical engineering*, *5*(2), 1415-1422.

Song, M., Jin, B., Xiao, R., Yang, L., Wu, Y., Zhong, Z. and Huang, Y. (2013). The Comparison of Two Activation Techniques to Prepare Activated Carbon from Corn Cob. *Biomass and Bioenergy, 48*, 250-256.

Southern, T. G. (1995). Technical Solutions to the Color Problem: A Critical Review. In Cooper, P. (Ed.). *Color in Dye House Effluent*. (pp. 73–75). Bradford, UK: The Society of Dyers and Colorists.

Srivastava, S., Sinha, R. and Roy, D. (2004). Toxicological Effects of Malachite Green. *Aquatic Toxicology, 66*(3), 319-329.

Sun, K., Jiang, J. and Cui, D. (2011). Preparation of Activated Carbon with Highly Developed Mesoporous Structure from Camellia oleifera Shell Through Water Vapor Gasification and Phosphoric Acid Modification. *Biomass and Bioenergy, 35*, 3643-3647.

Sun, X., Imai, T., Sekine, M., Higuchi, T., Yamamoto, K., Kanno, A. and Nakazono, S. (2014). Adsorption of phosphate using calcined Mg3–Fe layered double hydroxides in a fixed-bed column study. *Journal of Industrial and Engineering Chemistry*, *20*(5), 3623-3630.

Suteu, D. and Malutan, T. (2013). Industrial Cellolignin Wastes as Adsorbent for Removal of Methylene Blue Dye from Aqueous Solutions. *BioResources, 8*(1), 427-446.

Tan, I. A. W., Ahmad, A. L. and Hameed, B. H. (2000). Adsorption of Basic Dye on High-Surface-area Activated Carbon Prepared from Coconut Husk: Equilibrium, Kinetic and Thermodynamic Studies. *Journal of Hazardous Materials, 154*, 337-346.

Tan, I. A. W., Ahmad, A. L. and Hameed, B. H. (2008). Adsorption of basic dye using activated carbon prepared from oil palm shell: batch and fixed bed studies. *Desalination*, *225*(1-3), 13-28.

Tan, I. A. W., Hameed, B. H. and Ahmad, A. L. (2007). Equilibrium and kinetic studies on basic dye adsorption by oil palm fibre activated carbon. *Chemical Engineering Journal*, *127*(1-3), 111-119.

Tang, H., Zhou, W. and Zhang, L. (2012). Adsorption Isotherms and Kinetics Studies of Malachite Green on Chitin Hydrogels. *Journal of Hazardous Materials, 209*, 218-225.

Tang, S. H. (2016). *Textile Sludge Based Activated Carbon by Potassium Salts Activation for Malachite Green Removal*. Masters Thesis, Universiti Teknologi Malaysia, Skudai.

Tang, S. H. and Zaini, M. A. A. (2015a). Potassium hydroxide activation of activated carbon: a commentary. *Carbon Letter, 16*(4), 275-280.

Tang, S. H. and Zaini, M. A. A. (2015b). Isotherm studies of methylene blue adsorption onto potassium salts-modified textile sludge. *Jurnal Teknologi, 74*(7), 57-63.

Tang, S. H. and Zaini, M. A. A. (2016). Chapter 2 Dyes - Classification and Effective Removal Techniques. In Taylor, J. C. (Ed.). *Advances in Chemical Research Volume 30.* (pp.31-46). New York :Nova Science Publishers, Inc.

Tang, S. H. and Zaini, M. A. A. (2017). Malachite green adsorption by potassium salts-activated carbons derived from textile sludge: Equilibrium, kinetics and thermodynamics studies. *Asia-Pacific Journal of Chemical Engineering*, *12*(1), 159-172.

Tang, S. H. and Zaini, M. A. A. (2019). Preparation of textile sludge-derived activated carbons via KI and KOH activation for fast and efficient removal of methylene blue. *Desalination and Water Treatment*, *138*, 335-345.

Tanyol, M. (2017). Rapid malachite green removal from aqueous solution by natural zeolite: process optimization by response surface methodology. *Desalination and Water Treatment, 65*, 294-303.

Temkin, M. I. and Pyzhev, V. (1940). Kinetics of Ammonia Synthesis on Promoted Iron Catalysts. *Acta Physiochim. URSS, 12*(3), 217-222

Thomas, H. C. (1944). Heterogeneous ion exchange in a flowing system. *Journal of the American Chemical Society, 66*(10), 1664-1666.

Tongur, S. and Aydin, M. E. (2013). Adsorption kinetics of chloroform from aqueous solutions onto activated lignite. *CLEAN–Soil, Air, Water*, *41*(1), 32-36.

Toptas, A., Demierege, S., Mavioglu Ayan, E. and Yanik, J. (2014). Spent mushroom compost as biosorbent for dye biosorption. *CLEAN–Soil, Air, Water*, *42*(12), 1721-1728.

Toth, J. (1971). State Equations of Solid Gas Interface Layer. *Acta Chimica (Academiae Scientiarum) Hungaricae, 69,* 311-317.

Tsibranska, I. and Hristova, E. (2011). Comparison of Different Kinetic Models for Adsorption of Heavy Metals onto Activated Carbon from Apricot Stones. *Bulgarian Chemical Communications, 43*(3), 370-377.

Van der Bruggen, B., Schaep, J., Wilms, D. and Vandecasteele, C. (1999). Influence of molecular size, polarity and charge on the retention of organic molecules by nanofiltration. *Journal of Membrane Science, 156*(1), 29-41.

Viegas, R. M., Campinas, M., Costa, H. and Rosa, M. J. (2014). How do the HSDM and Boyd's model compare for estimating intraparticle diffusion coefficients in adsorption processes. *Adsorption*, *20*(5-6), 737-746.

Vijayakumar, G., Tamilarasan, R. and Dharmendirakumar, M. (2012). Adsorption, Kinetic, Equilibrium and Thermodynamic studies on the removal of basic dye Rhodamine-B from aqueous solution by the use of natural adsorbent perlite. *J. Mater. Environ. Sci*, *3*(1), 157-170.

Vix-Guterl, C., Frackowiak, E., Jurewicz, K., Friebe, M., Parmentier, J. and Beguin, F. (2005). Electrochemical Energy Storage in Ordered Porous Carbon Materials. *Carbon, 43*(6), 1293-1302.

Wang, J. and Kaskel, S. (2012). KOH activation of carbon-based materials for energy storage. *Journal of Materials Chemistry*, *22*(45), 23710-23725.

Wang, L. G. and Yan, G. B. (2011). Adsorptive Removal of Direct Yellow 161 Dyes from Aqueous Solution Using Bamboo Charcoals Activated with Different Chemicals. *Desalination, 274*, 81-90.

Wang, Y. H., Lin, S. H., and Juang, R. S. (2003). Removal of heavy metal ions from aqueous solutions using various low-cost adsorbents. *Journal of Hazardous Materials, 102*(2), 291-302.

Weber, T. W. and Chakravorti, R. K. (1974). Pore and Solid Diffusion Models for Fixed-bed Adsorbers. *AIChE Journal, 20*(2), 228-238.

Weber, W. J. and Morris, J. C. (1962). Removal of Biologically Resistant Pollutants from Waste Waters by Adsorption. *Proceedings of the International Conference on Advances in Water Pollution Research*. 2-6 September. New York: 2, 231-266.

Weber, W. J. and Smith, E. H. (1987). Simulation and design models for adsorption processes. *Environmental science & technology*, *21*(11), 1040-1050.

Werker, A. G. and Hall, E. R. (2004). Development and application of a quasi-static Langmuir isotherm for modelling selected resin acid fate in pulp mill wastewater treatment. *Water research*, *38*(8), 1995-2008.

Werle, S. and Dudziak, M. (2014). Analysis of organic and inorganic contaminants in dried sewage sludge and by-products of dried sewage sludge gasification. *Energies*, *7*(1), 462-476.

Wong, S., Yac'cob, N. A. N., Ngadi, N., Hassan, O. and Inuwa, I. M. (2018). From pollutant to solution of wastewater pollution: Synthesis of activated carbon from textile sludge for dye adsorption. *Chinese Journal of Chemical Engineering*, *26*(4), 870-878.

Wong, Y. C., Szeto, Y. S., Cheung, W. and McKay, G. (2004). Adsorption of Acid Dyes on Chitosan-Equilibrium Isotherm Analyses. *Process Biochemistry, 39*(6), 695-704.

Wu, C., Song, M., Jin, B., Wu, Y. and Huang, Y. (2013). Effect of Biomass Addition on the Surface and Adsorption Characterization of Carbon-Based Adsorbents from Sewage Sludge. *Journal of Environmental Science, 25*(2), 405-412.

Wu, F. C., Liu, B. L., Wu, K. T. and Tseng, R. L. (2010). A New Linear Form Analysis of Redlich–Peterson Isotherm Equation for the Adsorptions of Dyes. *Chemical Engineering Journal, 162*(1), 21-27.

Wu, F. C., Tseng, R.L. and Juang, R. S. (2009). Initial Behavior of Intraparticle Diffusion Model Used in the Description of Adsorption Kinetics. *Chemical Engineering Journal*, *153*, 1-8.

Wu, Y., Wang, Y., Wang, J., Xu, S., Yu, L., Philippe, C., and Wintgens, T. (2016). Nitrate removal from water by new polymeric adsorbent modified with amino and quaternary ammonium groups: Batch and column adsorption study. *Journal of the Taiwan Institute of Chemical Engineers*, *66*, 191-199.

Xu, Z., Cai, J. G., and Pan, B. C. (2013). Mathematically modeling fixed-bed adsorption in aqueous systems. J*ournal of Zhejiang University SCIENCE A, 14*(3), 155-176.

Xue, J., Cui, Q., Bai, Y., Wu, Y., Gao, Y., Li, L., and Qiao, N. (2016). Optimization of adsorption conditions for the removal of petroleum compounds from marine environment using modified activated carbon fiber by response surface methodology. *Environmental Progress & Sustainable Energy, 35*(5), 1400-1406.

Yagub, M. T., Sen, T. K., Afroze, S., and Ang, H. M. (2015). Fixed-bed dynamic column adsorption study of methylene blue (MB) onto pine cone. *Desalination and Water Treatment, 55*(4), 1026-1039.

Yang, K., Peng, J., Srinivasakannan, C., Zhang, L., Xia, H. and Duan, X. (2010). Preparation of High Surface Area Activated Carbon from Coconut Shells Using Microwave Heating. *Bioresource Technology, 101*(15), 6163-6169.

Yang, R. T. (1997). *Gas Separation by Adsorption Processes*. London: Imperial College Press.

Yao, Y. J., Xu, F. F., Chen, M., Xu, Z. X. and Zhu, Z. W. (2010). Adsorption Behavior of Methylene Blue on Carbon Nanotubes. *Bioresource Technology, 101,* 3040-3046.

Yek, P. N. Y., Liew, R. K., Osman, M. S., Lee, C. L., Chuah, J. H., Park, Y. K. and Lam, S. S. (2019). Microwave steam activation, an innovative pyrolysis approach to convert waste palm shell into highly microporous activated carbon. *Journal of Environmental Management, 236*, 245-253.

Yoon, Y. H., and Nelson, J. H. (1984). Application of gas adsorption kinetics I. theoretical model for respirator cartridge service life. *The American Industrial Hygiene Association Journal, 45*(8), 509-516.

Yu, Q., Li, M., Ning, P., Yi, H., and Tang, X. (2014). Preparation and Phosphine Adsorption of Activated Carbon Prepared from Walnut Shells by KOH Chemical Activation. *Separation Science and Technology*, *49*(15), 2366-2375.

Zaini, M. A. A. and Kamaruddin, M. J. (2013). Crirical Issues in Microwave-Assisted Activated Carbon Preparation. *Journal of Analytical and Applied Pyrolysis, 101*, 238-241.

Zaini, M. A. A., and Jusoh, N. Y. (2017). Evaluation of Treated and Untreated Sludge from Yarn Processing Factory as Adsorbent Candidates for Dye Removal. *Chiang Mai Journal of Science*, *44*(2), 508-517.

Zainuddin, M. F., Rosnah, S., Noriznan, M. M. and Dahlan, I. (2014). Effect of moisture content on physical properties of animal feed pellets from pineapple plant waste. *Agriculture and Agricultural Science Procedia*, *2*, 224-230.

Zambrano, A. P., Takano, C., Mourao, M. B., and Tagusagawa, S. Y. (2016). Binder Behavior on Chromite-Carbon Composite Pellets. *Materials Research, 19*(6), 1344-1350.

Zawadzki, J. (1980). IR Spectroscopic Investigations of the Mechanism of Oxidation of Carbonaceous Films with HNO_3 Solution. *Carbon, 18*(4), 281-285.

Zeldowitsch, J. (1934). Adsorption Site Energy Distribution. *Acta Physicochimica. URSS, 1*, 961-973.

Zhang, H., Yan, Y. and Yang, L. (2008). Preparation of activated carbons from sawdust by chemical activation. *Adsorption Science & Technology*, *26*(7), 533-543.

Zhu, X., Gao, Y., Yue, Q., Kan, Y., Kong, W., and Gao, B. (2017). Preparation of green alga-based activated carbon with lower impregnation ratio and less activation time by potassium tartrate for adsorption of chloramphenicol. *Ecotoxicology and Environmental Safety, 145*, 289-294.