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Utilization of active carbon produced from local materials as adsorbent for heavy metal ions from industrial wastewater

A Thesis

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for requirements of Master of Science)**

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Mohamed Youssef Abdelnaeim

Abbreviations:

AC	Activated carbon
APHA	American Public Health Association
Atm.	Atmosphere
b	Langmuir constant
B	Constant related to heat of sorption
BET	(Brunauer, Emmett and Teller) method
BJH	(Barret-Joyner-Halenda) method
b _T	Tempkin isotherm constant
C _e	Concentration at equilibrium
C _o	Initial concentration
CR	Common reed
D-R	(Dubinin-Radushkevich) equation
E	Mean free energy of sorption
ESCA	Electron Spectroscopy for Chemical Analysis
ESR	Electron Spin Resonance
ϵ	Polynya potential in Dubinin-Radushkevich isotherm model
FTIR	Fourier Transform Infrared Spectroscopy
IARAC	Aeronautical Information Regulation And Control
IDLH	Immediately dangerous to life and health
IUPAC	International Union of Pure and Applied Chemistry
K _{ad}	Pseudo-first order rate constant
K _f	Freundlich constant
K _i	Rate constant of intraparticle diffusion model

K_s	Pseudo-second order rate constant
MB	Methylene blue dye
n	Heterogeneity factor
NIOSH	National institute for occupational safety and health
OSHA	Occupational Safety and Health Administration
PA	Phosphoric acid
PEL	Permissible exposure limit
q_e	Adsorption capacity at equilibrium
q_o	Maximum amount of adsorption to complete monolayer coverage on surface
q_s	Dubinin-Radushkevich adsorption constant
q_t	Amount adsorbed in the each time interval (t)
R	Gas constant (=8.314 J/mol K) or (1.985 cal/mol K)
R^2	Correlation coefficient
REL	Recommended exposure limit
R_L	Separation factor
R_p	The average radius of the pores
S_{BET}	Surface area calculated according to BET equation
STP	Standard temperature and pressure
T	Temperature
TPD	Temperature programmed desorption
TWA	Time-weighted average
V	Volume of solution in Liter
$V_{0.99}$	Volume of liquid nitrogen corresponding to the amount adsorbed at a relative pressure $P/P_o \approx 0.99$

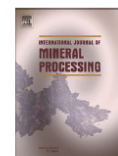
V_{meso}	Volume of mesopores
V_{micro}	Volume of micropores
V_P	Total pores volumes
W	Weight of adsorbate
WHO	World health organization
W_t	Weight of phosphoric acid

Abstract

This study investigates the following prospects of (i) the preparation facilities of activated carbon from Common Reed (CR) using chemical activation with H_3PO_4 (PA) under flowing of two different gases (Nitrogen & Air), and (ii) the adsorption performance of the produced activated carbon (AC) towards the removal of Cu(II), Cd(II) and methylene blue dye from their aqueous solutions. Activated carbons (ACs) obtained were characterized using FT-IR and N_2 adsorption/desorption isotherms. The adsorption data were studied for adsorption isotherms of Langmuir, Freundlich, Dubinin-Radushkevich and Temkin models. Also Kinetic studies were done according to pseudo-first order, pseudo-second order and Intraparticle diffusion models. Adsorption of Cu(II) and Cd(II) were best fitted with Dubinin-Radushkevich and Temkin adsorption isotherms, while adsorption of methylene blue was fitted with Langmuir and Dubinin-Radushkevich isotherm models and pseudo-second order kinetic model. The best conditions of preparation were (30% PA – air) for Cu(II) adsorption, (50% - N_2) for Cd(II) adsorption, and (50% - air) for dye adsorption. The total surface areas (S_{BET}) were between 1067.73 and 1192.85 m^2/g . The adsorption capacity of Cu(II) and Cd(II) were 47.00 mg/g and 83.43 mg/g respectively, while the maximum adsorption capacity of dye was 314.4 mg/g. The results indicated that CR could be employed as a low-cost alternative for the preparation of activated carbon and the removal of heavy metals ions and organic pollutants from effluents.

Keywords:

Common Reed, Activated carbon, Chemical activation, Adsorption, Heavy metals ions, Dye pollutant, Methylene blue, Langmuir, Freundlich, Dubinin-Radushkevich, Temkin, Pseudo-first order, Pseudo-second order, Intraparticle diffusion model.



Impact of chemical activation on the adsorption performance of common reed towards Cu(II) and Cd(II)



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ABSTRACT

The adsorption of Cu(II) and Cd(II) from aqueous solution was studied by Common Reed (CR) activated with different concentrations of H₃PO₄ (PA) and carbonized at 500 °C under flowing of different atmospheres (nitrogen and air). Activated carbons (ACs) obtained were characterized using FT-IR and N₂ adsorption/desorption isotherm. The adsorption data were studied for adsorption isotherms of Langmuir, Freundlich, Dubinin-Radushkevich and Temkin models. Adsorption of Cu(II) and Cd(II) was best fitted with Dubinin-Radushkevich and Temkin adsorption isotherms. The best conditions of preparation were 30% PA in the air for Cu(II) adsorption and 50% in N₂ for Cd(II) adsorption, with total surface area (SBET) of 1192.85 m²/g and 1181.44 m²/g respectively. The adsorption capacity of Cu(II) and Cd(II) were 47.00 mg/g and 83.43 mg/g respectively. The results indicated that CR could be employed as a low-cost alternative for the removal of heavy metals ions from effluents.

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1. Introduction

Water contaminated with metal ions can cause several health problems. Heavy metal ions such as cadmium, zinc, nickel, chromium, copper and lead can bio-accumulate to be toxic compounds through the food chain. Cadmium is responsible for kidney tubular impairment and osteomalacia. Cadmium, zinc and manganese ions are reported to affect on the ion regulation if present in sufficient concentrations. They are known to affect calcium metabolism, development and skeletal calcification with long term effect and spawning and recruitment of aquatic lives. The PH change of water bodies as a result of effluent can cause serious change in the marine environment which can affect resources especially around the coastal areas (Igwe and Abia, 2007).

There are a lot of technologies have been developed over the recent decades to remove heavy metal ions from industrial wastewater, which include coagulation/flocculation process, membrane filtration, electro-dialysis, activated carbon adsorption, reverse osmosis, ion exchange, and solvent extraction. Most of them are complicated, time-consuming and require skilled personnel. Recently, non-conventional and low-cost agricultural by-products have been employed to be important

adsorbent for the removal of metals and organics from municipal and industrial wastewater (Igwe and Abia, 2007). This is because of their renewable nature and lingo-cellulosic content (57–77%) (Gupta et al., 2013).

The carbonaceous adsorbent is a porous matter with a high surface area, a great adsorption capacity and an effective regeneration. Carboxylic, carbonylic, lactonic, phenolic, aldehydic, and other organic functional groups are located at the edge of hexagonal rings of carbon in layer planes and are responsible for surface reactivity of activated carbon. Ionization of the functional groups depends on pH of the solution and leads to a build-up of a charged surface between the solid surface and the bulk of the solution. The type and concentration of surface functional groups depend on the preparation method and the sort of the precursor (Momčilović et al., 2011).

Orthophosphoric acid (PA), H₃PO₄, is a common activating agent whose use has been extensively reported for preparing activated carbons from agricultural by-products, wood, natural as well as synthetic carbons. PA promotes the bond cleavage in the biopolymers and dehydration at low temperatures, and then extensive cross-linking that binds volatile matter into the carbon product and increases the carbon yield. The mechanism of PA activation of biomass occurs through various steps like cellulose depolymerization, biopolymers dehydration, the formation of aromatic rings and formation of phosphate groups. This makes activated carbons be prepared with high surface areas. Activation conditions thus depend on the nature of the precursor, i.e., on the relative amounts of cellulose, hemicellulose, lignin and ashes (Gupta et al., 2013) (Shi et al., 2010) (Fierro et al., 2010).

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contents	Page No.
Abbreviations	1
Abstract	4
Contents	6
B. List of figures	9
C. List of tables	11
Chapter I: introduction and aim of the work	13
Part 1: Introduction	14
1.1. Human evolution and the environment	15
1.2. Environmental management	16
1.3 Technologies of wastewater treatment	17
1.3.1. Adsorption remediation methods	19
1.3.2. Economic utility of adsorption remediation methods	20
1.4. Activated carbon	25
1.4.1. Uses and world consumption of activated carbon	26
1.4.2. Raw materials of activated carbon	27
1.4.3. Preparation of activated carbon	28
1.4.3.1. Physical activation methods	28
1.4.3.2. Chemical activation methods	29
1.4.3.3. Suitable preparation methods	29
1.4.4. Characteristics of activated carbon	32
1.4.4.1. Crystalline structure	32
1.4.4.2. Porous structure	36
1.4.4.2.1. Origin and classification of pores in solid materials	36
1.4.4.2.2. IUPAC classification of pores	38
1.4.5. Effect of precursor and activation methods	40
1.4.6. Pore development during preparation process	40
1.4.7. Chemical structure of activated carbon	42
1.4.7.1. Carbon-Oxygen surface groups	43
1.4.7.2. Reactions of carbon with oxygen	44
1.4.7.3. Types of carbon-oxygen surface groups	45
1.4.7.4. Characterization of carbon-oxygen surface groups	48
Part 2: The work high lights& Aims	49
1.5. Work's plan	50
1.5.1. Preparation of activated carbon adsorbents	50
1.5.1.1. Raw materials (precursors)	50
1.5.1.2. Activating agents and preparation methods	50
1.5.2. Characterization of activated carbon adsorbents	51

1.5.3. Applications of activated carbon materials	51
1.5.3.1. Adsorption of Copper	53
1.5.3.2. Adsorption of Cadmium	53
1.5.3.3. Adsorption of Methylene Blue	54
1.6. Aims of the work	55
Chapter 2: Materials and Methods	57
2.1. Materials	58
2.2. Activated carbon	58
2.3. Characterization of activated carbon	59
2.3.1. The yield and ash content of activated carbon	59
2.3.2. Chemical structure characterization techniques	60
2.3.3. Surface textural characterization techniques	60
2.4. Application of activated carbon materials	62
2.4.1. Heavy metal ions adsorption	63
2.4.2. Methylene blue adsorption	64
2.4.2.1. Methylene blue adsorption isotherms	64
2.4.2.2. Effect of pH	65
2.4.2.3. Effect of contact time and adsorbent dose on the adsorption of methylene blue	65
2.4.2.4. Effect of initial concentration	65
2.4.3. Adsorption isotherm models	66
2.4.4. Kinetic studies	69
2.4.4.1. Experimental conditions	69
2.4.4.2. Adsorption kinetics models	70
Chapter 3: Results and Discussions	72
Part 1: Characterization of activated carbon	73
3.1.1. Effect of phosphoric acid concentration on yield and ash content	74
3.1.2. FT-IR of activated carbon	75
3.1.3. The pore structure of activated carbon	79
Part 2: Adsorption of heavy metals ions	85
3.2.1. Adsorption of copper ions from solution	86
3.2.1.1. The removal percentage of copper ions	86
3.2.1.2. Adsorption of copper ions from aqueous solution	87
3.2.2. Adsorption of cadmium ions from solutions	93
3.2.2.1. The removal percentage of cadmium ions	93
3.2.2.2. Adsorption of cadmium ions from aqueous solution	94
3.2.3. Heavy metal ions adsorption mechanism	99
3.2.4. Evaluation of developed activated carbon	100
Part 3: Adsorption of organic matters	103
3.3. Methylene blue adsorption	104

3.3.1. Methylene blue removal percentage	104
3.3.2. Adsorption isotherms and parameters	105
3.3.3. Effect of pH on the adsorption of methylene blue	110
3.3.4. Effect of contact time and adsorbent dose on the adsorption of methylene blue	112
3.3.5. Effect of initial concentration of methylene blue on the adsorption	113
3.3.6. Kinetic studies on the adsorption of methylene blue	115
3.3.7. Evaluation of developed activated carbon	118
Conclusion	121
References	125
Arabic summary	143

B. List of figures		
Figure No.	Figure Address	Page No.
1	Fanklin's representations of (a) graphitizing and (b) nongraphitizing carbons.	33
2	Comparison between Graphite and Turbostratic structure of AC	35
3	Oxygen surface groups of acidic & basic characters	46
4	A model of a fragment of an oxidized active carbon surface proposed.	48
5	Molecular structure of methylene blue	55
6	Common reed after being collected and cleaned	58
7	The relation between PA concentration and both yield and ash content in both N ₂ and air burning atmosphere.	75
8	FT-IR analysis of the six ACs samples	77-78
9	N ₂ adsorption / desorption isotherms for ACs prepared in (a) N ₂ and (b) air.	80
10	Micro-, Meso-pores sizes distribution of ACs using (BJH) method.	83-84
11	Comparison between copper ions removal percentage by ACs prepared	86
12	Cu(II) adsorption plotting by (a) Langmuir isotherm, (b) Freundlich isotherm, (c) Dubinin-Radushkevich isotherm, (d) Temkin isotherm.	88-91
13	Comparison between cadmium ions removal percentage by ACs prepared	93

14	Cd(II) adsorption plotting by (a) Langmuir isotherm, (b) Freundlich isotherm, (c) Dubinin-Radushkevich isotherm, (d) Temkin isotherm.	95-98
15	The removal behavior of dye on ACs prepared in (a) N ₂ , (b) air, with concentration variation	104-105
16	MB adsorption plotting by (a) Langmuir isotherm, (b) Freundlich isotherm, (c) Dubinin-Radushkevich isotherm, (d) Temkin isotherm.	106-109
17	Percentage removal of MB by AC.6 according to pH variation	111
18	Removal percentage of MB by adsorbent dose AC.6 and time variation	113
19	Removal percentage of MB by AC.6 and initial concentration variation	114
20	Maximum quantities of MB adsorbed by AC.6 by variation of initial concentration	114
21	MB adsorption isotherm plotting by Langmuir model, initial concentrations from 200 to 800 mg/L, using AC.6	115
22	MB adsorption kinetic by (a) pseudo-first order, (b) pseudo-second order, (c) intraparticle diffusion models, using AC.6 in the removal	117

C. List of tables		
Table No.	Table Address	Page No.
1	Advantages and disadvantages of activated carbon and other conventional adsorbents for solution remediation	23-24
2	Heavy metals in some major industries.	52
3	Average releases of heavy metals into the Mississippi River from a large metropolitan wastewater treatment plant in SL. Paul, Minnesota.	52
4	Preparation conditions of six ACs at 500°C	59
5	The conditions of adsorption exp.	64
6	Different isotherm equations in linear and nonlinear forms.	66
7	The texture parameters of ACs	81
8	The parameters of Cu (II) adsorption evaluated by the application of (a)langmuir isotherm (b)Freundlich isotherm (c)Dubinin-Radushkevich isotherm (d)Temkin isotherm.	92
9	The parameters of Cd (II) adsorption evaluated by the application of (a)langmuir isotherm (b)Freundlich isotherm (c)Dubinin-Radushkevich isotherm (d)Temkin isotherm.	99
10	Comparison of copper cation adsorption capacity onto ACs from different agricultural wastes.	101
11	Comparison of cadmium cation adsorption capacity onto adsorbents from different agricultural wastes.	102
12	The parameters of MB adsorption evaluated by the application of (a)langmuir isotherm (b)Freundlich isotherm (c)Dubinin-Radushkevich	110

	isotherm(d) Temkin isotherm.	
13	Parameters of MB adsorption kinetics models by using AC.6	118
14	Adsorption capacity of ACs from Common Reed in relevant literature studies	119
15	Comparison of MB maximum adsorption onto ACs from different agricultural wastes by conventional heating.	120