Ain Shams University

Faculty of Science

Chemistry Department

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

A Thesis

(Submitted for the degree of Master of Science as a partial fulfillment for requirements of Master of Science)

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2017

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Acknowledgment

First and foremost thanks are due to Allah, the most beneficent, unlimited and continuous blessing on me, and for all gifts He gave to me.

I wish to express my deepest gratitude and great thanks to **Prof. Dr. Mohamed Fathy El-Shahat,** Professor of Analytical and Inorganic Chemistry, Faculty of Science, Ain Shams University, **Prof. Dr. Iman Yousef El-Sherif**, Professor of Water Chemistry at Water Pollution Research Department, National Research Centre, and **Assistant Prof. Atia El-Sayed Atia**, Assistant Professor of Inorganic Chemistry, Faculty of Science, Ain Shams University, for suggesting the problem, supervision, precious suggestion and valuable discussions which were so willingly given throughout this work.

I wish also to express my sincere gratitude and special appreciation to **Prof. Dr. Amina Abdel-Maged Attia**, Professor of Surface Chemistry at Physical Chemistry Department, National Research Center, **Assistant Prof. Nady Attia Fathy**, Assistant Professor of Surface Chemistry at Physical Chemistry Department, National Research Center, and **Dr. Shaimaa El-Wakeel**, Researcher at water pollution research department, National Research Center, for sincere supervision, precious suggestions and valuable discussions which were so willingly given throughout this work. My deepest gratitude is to all colleagues and staff members of Chemistry Department, Faculty of Science, Ain Shams University.

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 Adminstration
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
Wt	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 Tempkin 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 Tempkin 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.

International Journal of Mineral Processing 157 (2016) 80–88

Contents lists available at ScienceDirect

International Journal of Mineral Processing

journal homepage: www.elsevier.com/locate/ijminpro

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

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ARTICLE INFO

Article history:
Received 26 January 2016
Received in revised form 27 July 2016
Accepted 30 September 2016
Available online 3 October 2016

Keywords:
Adsorption
Common reed
Dubinin-Radushkevich
Freundlich
Langmuir
Temkin

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 Tempkin models. Adsorption of Cu(II) and Cd(II) was best fitted with Dubinin-Radushkevich and Tempkin 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 m^2/g and 1181.44 m^2/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, electrodialysis, 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), H_3PO_4, 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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http://dx.doi.org/10.1016/j.minpro.2016.09.013
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