Cairo University

ADSORPTION OF PHENOL FROM AQUEOUS SOLUTIONS USING ENGINEERED AND NATURAL ADSORBENTS

By

MOHAMED MEDHAT MOHAMED MAHMOUD HASSAN

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
IN
CIVIL ENGINEERING – PUBLIC WORKS

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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GIZA, EGYPT
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ADSORPTION OF PHENOL FROM AQUEOUS SOLUTIONS USING ENGINEERED AND NATURAL ADSORBENTS

Key Words:
Adsorption; Phenol; Adsorption Kinetics; Adsorption Equilibrium; FTIR

Summary:

This thesis conducted an investigation on the ability of six different adsorbents (aluminum oxide, zinc oxide, titanium dioxide, kaolin, fuller's earth, and bentonite) to remove phenol from aqueous solutions through adsorption. The points of zero charge for aluminum oxide, zinc oxide, titanium dioxide, kaolin, fuller's earth, and bentonite were found to be 9.0, 7.2, 6.9, 5.9, 8, and 7.7 respectively. Adsorption of phenol as a function of pH level was studied. Results revealed increase in removal efficiency with decrease in pH value. The highest removal efficiencies for aluminum oxide and zinc oxide, titanium dioxide, kaolin, fuller's earth, and bentonite, respectively, at adsorbent pH = 4.5 and 0.5 g were 45.2%, 36%, 41.5%, 50%, 36.7%, and 61.1% respectively. Various kinetics models were studied and Phenol uptake onto all adsorbents can be expressed by Psuedo-second order kinetics. As for equilibrium studies not all adsorbents were best described by the same isotherm model. As Frendluich isotherm best describes aluminum oxide, bentonite, and fuller's earth studies, Whereas Temkin isotherm best describes kaolin and zinc oxide, As for titanium, Dubinin-Radushkevich isotherm best described its equilibrium data. FTIR and SEM were used in conducting investigation on adsorbents with results revealing adsorption occurrence.

Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

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Table of Content

List of tables

List of figures

Nomenclature

Al	Aluminum
AOP	Advanced oxidation process
Ce	Adsorbate equilibrium concentration
cm	centimeter
Co	Adsorbate initial concentration
CO_2	Carbon dioxide
COD	chemical oxygen demand
°C	Celsius degree
Eg	Band gab energy
FE	Fuller's earth
Fe_2O_3	Iron Oxide
FTIR	Fourier-transform infrared spectroscopy
gm	gram
H_2O	Water
HO•	Hydroxyl radical
K	Kaolin
K1	Psuedo-First-Order Constant
K2	Psuedo-Second-Order Constant
K_{id}	Expression constant in intra-particle diffusion model
KV	Kilo Volt
°K	Kelvin degree
l	liter
M	Mass
m	Meter
mA	milliampere
mg	Milligram
min	minute
ml	Milliliter
mmol	millimole
mol	Mole
Ɵ	Boundary layer thickness related constant
O•	Oxygen radical
O_2	Oxygen
O_{-2}	Superoxide radicals
O_3	Ozone
PFO	Psuedo-First-Order
pH	Log10 of Hydrogen ion concentration
pHpzc	point of zero charge

PSO	Psuedo-Second-Order
qe	amount of adsobate at equilibrium
qt	amount of adsobate at time t
R	Universal gas constant
R^2	coefficient of determination
rpm	revolution per minute
s	second
SEM	Scanning electron microscope
T	Absolute temperature
t	time
TiO_2	Titanium dioxide
V	Volt
Vol.	Volume
WwTP	Wastewater Treatment plant
ZnO	Zinc oxide

Abstract

This thesis conducted an investigation on the ability of engineered adsorbents (aluminum oxide, zinc oxide, and titanium dioxide) and natural adsorbents (kaolin, fuller's earth, and bentonite) to remove phenol from aqueous solutions through adsorption. The points of zero charge for aluminum oxide, zinc oxide, and titanium dioxide were found to be 9.0, 7.2, and 6.9 respectively. The points of zero charge for kaolin, fuller's earth, and bentonite were found to be 5.9, 8, and 7.7, respectively. Adsorption of phenol as a function of pH level was studied. Results revealed increase in removal efficiency with decrease in pH value. The highest removal efficiencies for aluminum oxide and zinc oxide, as well as for titanium dioxide at adsorbent pH = 4.5 and 0.5 g were 45.2%, 36% and 41.5% respectively. The maximum removal efficiencies were 50%, 36.7%, and 61.1% for kaolin, fuller's earth, and bentonite, respectively, for 0.5 g of adsorbent and pH = 4.5. Exploration of the adsorption procedure's experimental data was undertaken through fitting to various kinetic models in determining the adsorption kinetics and mechanisms. Phenol uptake onto all adsorbents can be expressed by Psuedo-second order kinetics. Examination of the equilibrium data was made through the fitting to different isotherm models. Equilibrium studies demonstrated the possibility of Frendluich isotherm, Temkin isotherm, and Dubinin-Radushkevich isotherm respectively expressing the adsorption isotherms for aluminum oxide, zinc oxide, and titanium dioxide. Whereas the Freundlich isotherm well suits the experimental data for adsorption onto bentonite and fuller's earth, and Temkin isotherm well suits the experimental data for uptake onto kaolin. FTIR and SEM were used in conducting investigation on adsorbents with results revealing adsorption occurrence.