



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
GIZA, EGYPT
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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 Pseudo-second order kinetics. As for equilibrium studies not all adsorbents were best described by the same isotherm model. As Freundlich 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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Date:/..../2019

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Table of Content

List of tables	v
List of figures	vi
Nomenclature	ix
Abstract	xi
Chapter 1 : Introduction	1
Chapter 2 : Literature review	2
2.1 Introduction.....	2
2.2 Industrial wastewater containing phenol.....	2
2.3 Treatment of wastewater containing phenol.....	3
2.3.1 Photocatalytic degradation of phenolic compounds	4
2.3.2 Ozonation.....	5
2.3.3 Extraction method	5
2.3.4 Biological method	7
2.3.5 Membrane-based separation method.....	8
2.3.6 Electro-Fenton method	9
2.3.7 Adsorption	10
2.4 Adsorption	11
2.4.1 Introduction.....	11
2.4.2 Adsorption kinetics	11
2.4.3 Adsorption isotherms	14
2.5 Previous researches on adsorption of phenol.....	17
2.5.1 Adsorption of phenol onto activated carbons having different textural and surface properties.....	17
2.5.2 Adsorption of phenol using different types of activated bentonites	18
2.5.3 Removal of phenol from aqueous solutions by adsorption	18
2.5.4 Equilibrium, kinetics and thermodynamic studies for adsorption of As(III) on activated alumina	19
2.5.5 Evaluation of Fuller’s earth for the adsorption of mercury from aqueous solutions: A comparative study with activated carbon	19
Chapter 3 : Experimental work	20
3.1 Characteristics of wastewater and adsorbents	20
3.1.1 Characteristics of wastewater	20
3.1.2 Adsorbents	21
3.2 System Setup and operating procedures.....	28
3.2.1 System setup and Devices used during experimental work	28
3.2.2 Operating procedures	34
3.3 Measurements	34
Chapter 4 : Results and Discussion	35
4.1 Introduction.....	35
4.2 Synthetic wastewater analysis.....	35
4.2.1 Determination of Point of zero Charge (pHpzc) :-	35
4.2.2 Determination of optimum pH value for phenol uptake	39
4.2.3 Adsorption Kinetics.....	42

4.2.4	Adsorption Kinetics Mechanism Study.....	52
4.2.5	Equilibrium Studies.....	58
4.3	Analysis of adsorbents' surface	72
4.3.1	FTIR spectroscopy	72
4.3.2	Studying adsorbents Morphology via SEM.....	75
4.4	Industrial wastewater analysis	82
4.5	Cost analysis	82
4.5.1	Cost of Construction and Equipment	82
4.5.2	Cost of Chemicals	83
4.5.3	Cost of electricity	83
4.5.4	Total Cost	84
Chapter 5 : Conclusion and Recommendations		85
5.1	Conclusion	85
5.2	Future works recommendations	86
References.....		87

List of tables

Table 1: Cost of Chemicals.....	83
Table 2: Total Cost per adsorbent.....	84

List of figures

Figure 2.1: Schematic diagram of photocatalytic reactions for the degradation of organic contaminants	4
Figure 2.2: A photo describing adsorption phenomena.....	11
Figure 3.1: Phenol manufacturer case and characteristics	20
Figure 3.2: Phenol Crystals.....	21
Figure 3.3: Aluminum Oxide manufacturer case and characteristics	22
Figure 3.4: Aluminum powder.....	22
Figure 3.5: Bentonite manufacturer case and characteristics	23
Figure 3.6: Bentonite powder	23
Figure 3.7: Fuller’s earth manufacturer case and characteristics.....	24
Figure 3.8: Fuller’s earth powder.....	24
Figure 3.9: Kaolin manufacturer case and characteristics	25
Figure 3.10: Kaolin powder	25
Figure 3.11: Titanium oxide manufacturer case and characteristics	26
Figure 3.12: Titanium oxide powder.....	26
Figure 3.13: Zinc oxide manufacturer case and characteristics	27
Figure 3.14: Zinc oxide powder.....	27
Figure 3.15: Mettler scale	28
Figure 3.16: Falcon tube	29
Figure 3.17: Orbital shaker	30
Figure 3.18: Filter paper manufacturer casing.....	31
Figure 3.19: Filter paper	31
Figure 3.20: Air Cadet vacuum pump	32
Figure 3.21: inolab pH measuring device.....	32
Figure 3.22: Nanocolor 500D phenol measuring device	33
Figure 3.23: SEM Quanta 250	33
Figure 4.1: pH _{pzc} determination For Aluminum.....	36
Figure 4.2: pH _{pzc} determination For Bentonite	36
Figure 4.3: pH _{pzc} determination For Fuller's Earth.....	37
Figure 4.4: pH _{pzc} determination For Kaolin	37
Figure 4.5: pH _{pzc} determination For Titanium	38
Figure 4.6: pH _{pzc} determination For Zinc	38
Figure 4.7: Aluminum removal efficiency at different pH values	39
Figure 4.8: Bentonite removal efficiency at different pH values.....	40
Figure 4.9: Fuller's Earth removal efficiency at different pH values	40
Figure 4.10: Kaolin removal efficiency at different pH values	41
Figure 4.11: Titanium removal efficiency at different pH values.....	41
Figure 4.12: Zinc removal efficiency at different pH values.....	42
Figure 4.13: Fitting aluminum kinetics data using PFO equation	43
Figure 4.14: Fitting aluminum kinetics data using PSO equation	44
Figure 4.15: Fitting aluminum kinetics data using Elovich’s equation.....	44
Figure 4.16: Fitting bentonite kinetics data using PFO equation.....	45
Figure 4.17: Fitting bentonite kinetics data using PSO equation.....	45

Figure 4.18: Fitting bentonite kinetics data using Elovich's equation	46
Figure 4.19: Fitting fuller's earth kinetics data using PFO equation	46
Figure 4.20: Fitting fuller's earth kinetics data using PSO equation	47
Figure 4.21: Fitting fuller's earth kinetics data using Elovich's equation.....	47
Figure 4.22: Fitting kaolin kinetics data using PFO equation	48
Figure 4.23: Fitting kaolin kinetics data using PSO equation	48
Figure 4.24: Fitting kaolin kinetics data using Elovich's equation.....	49
Figure 4.25: Fitting titanium kinetics data using PFO equation	49
Figure 4.26: Fitting titanium kinetics data using PSO equation	50
Figure 4.27: Fitting titanium kinetics data using Elovich's equation	50
Figure 4.28: Fitting zinc kinetics data using PFO equation.....	51
Figure 4.29: Fitting zinc kinetics data using PSO equation.....	51
Figure 4.30: Fitting zinc kinetics data using Elovich's equation.....	52
Figure 4.31: Fitting aluminum kinetics data using intra-particle diffusion model	53
Figure 4.32: Fitting bentonite kinetics data using intra-particle diffusion model.....	53
Figure 4.33: Fitting fuller's earth kinetics data using intra-particle diffusion model.....	54
Figure 4.34: Fitting kaolin kinetics data using intra-particle diffusion model	54
Figure 4.35: Fitting titanium kinetics data using intra-particle diffusion model	55
Figure 4.36: Fitting zinc kinetics data using intra-particle diffusion model.....	55
Figure 4.37: Fitting aluminum kinetics data using Boyd model.....	56
Figure 4.38: Fitting bentonite kinetics data using Boyd model	56
Figure 4.39: Fitting fuller's earth kinetics data using Boyd model	57
Figure 4.40: Fitting kaolin kinetics data using Boyd model.....	57
Figure 4.41: Fitting titanium kinetics data using Boyd model.....	58
Figure 4.42: fitting zinc kinetics data using Boyd model.....	58
Figure 4.43: Fitting Aluminum's Equilibrium batch results using Langmuir isotherm.....	60
Figure 4.44: Fitting Aluminum's Equilibrium batch results using Freundlich isotherm	60
Figure 4.45: Fitting Aluminum's Equilibrium batch results using Temkin isotherm.....	61
Figure 4.46: Fitting Aluminum's Equilibrium batch results using Dubinin-Radushkevich isotherm	61
Figure 4.47: Fitting bentonite's Equilibrium batch results using Langmuir isotherm.....	62
Figure 4.48: Fitting bentonite's equilibrium batch results using Freundlich isotherm.....	62
Figure 4.49: Fitting bentonite's equilibrium batch results using Temkin isotherm	63
Figure 4.50: Fitting bentonite's equilibrium batch results using Dubinin-Radushkevich isotherm	63
Figure 4.51: Fitting filler's earth Equilibrium batch results using Langmuir isotherm.....	64
Figure 4.52: Fitting fuller's earth equilibrium batch results using Freundlich isotherm	64
Figure 4.53: Fitting fuller's earth equilibrium batch results using Temkin isotherm.....	65
Figure 4.54: Fitting fuller's earth equilibrium batch results using Dubinin-Radushkevich isotherm	65
Figure 4.55: Fitting kaolin's Equilibrium batch results using Langmuir isotherm	66
Figure 4.56: Fitting kaolin's equilibrium batch results using Freundlich isotherm	66
Figure 4.57: Fitting kaolin's equilibrium batch results using Temkin isotherm	67
Figure 4.58: Fitting kaolin's equilibrium batch results using Dubinin-Radushkevich isotherm	67
Figure 4.59: Fitting titanium's Equilibrium batch results using Langmuir isotherm	68

Figure 4.60: Fitting titanium's equilibrium batch results using Freundlich isotherm	68
Figure 4.61: Fitting titanium's equilibrium batch results using Temkin isotherm.....	69
Figure 4.62: Fitting titanium's equilibrium batch results using Dubinin-Radushkevich isotherm	69
Figure 4.63: Fitting zinc's Equilibrium batch results using Langmuir isotherm.....	70
Figure 4.64: Fitting zinc's equilibrium batch results using Freundlich isotherm.....	70
Figure 4.65: Fitting zinc's equilibrium batch results using Temkin isotherm	71
Figure 4.66: Fitting zinc's equilibrium batch results using Dubinin-Radushkevich isotherm.	71
Figure 4.67: Analysis of aluminum sludge via FTIR.....	72
Figure 4.68: Analysis of bentonite sludge via FTIR	73
Figure 4.69: Analysis of fuller's earth sludge via FTIR	73
Figure 4.70: Analysis of kaolin sludge via FTIR.....	74
Figure 4.71: Analysis of titanium sludge via FTIR.....	74
Figure 4.72: Analysis of zinc sludge via FTIR	75
Figure 4.73: Aluminum surface morphology before adsorption.....	76
Figure 4.74: Aluminum surface morphology after adsorption	76
Figure 4.75: Bentonite surface morphology before adsorption	77
Figure 4.76: Bentonite surface morphology after adsorption	77
Figure 4.77: Fuller's Earth surface morphology before adsorption.....	78
Figure 4.78: Fuller's Earth surface morphology after adsorption	78
Figure 4.79: Kaolin surface morphology before adsorption.....	79
Figure 4.80: Kaolin surface morphology after adsorption.....	79
Figure 4.81: Titanium surface morphology before adsorption	80
Figure 4.82: Titanium surface morphology after adsorption.....	80
Figure 4.83: Zinc surface morphology before adsorption	81
Figure 4.84: Zinc surface morphology after adsorption	81

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 gap energy
FE	Fuller's earth
Fe ₂ O ₃	Iron Oxide
FTIR	Fourier-transform infrared spectroscopy
gm	gram
H ₂ O	Water
HO•	Hydroxyl radical
K	Kaolin
K ₁	Pseudo-First-Order Constant
K ₂	Pseudo-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
Θ	Boundary layer thickness related constant
O•	Oxygen radical
O ₂	Oxygen
O ₂ ⁻	Superoxide radicals
O ₃	Ozone
PFO	Pseudo-First-Order
pH	Log ₁₀ of Hydrogen ion concentration
pH _{pzc}	point of zero charge

PSO	Pseudo-Second-Order
q _e	amount of adsorbate at equilibrium
q _t	amount of adsorbate 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 Pseudo-second order kinetics. Examination of the equilibrium data was made through the fitting to different isotherm models. Equilibrium studies demonstrated the possibility of Freundlich 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.