SYNTHESIS AND APPLICATION OF NANOPOROUS CARBON INCORPORATED WITH COBALT FERRITE COMPOSITE AND MOLECULARLY IMPRINTED POLYMER FOR MERCURY REMOVAL FROM WASTEWATER

By

LAWAL ABUBAKAR

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

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DEDICATION

My Entire Family and Friends

Abstract of Thesis was presented to the Senate of Universiti Putra Malaysia in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

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July 2023

Chair : Professor ChM. Nor Azah binti Yusof, PhD
Faculty : Science

Water pollution has been a major challenge to environmental scientists today due to the release of toxic heavy metals from various industries. Among various heavy metals, mercury [Hg(II)] is considered as highly toxic due to its carcinogenicity and various health disorders. Different sources of Hg(II) pollution include effluents from mining, leather tanning and electroplating industries. Among various technologies, adsorptive removal of Hg(II) by using different adsorbents is more promising and economical. Among various adsorbents used, nanoporous carbon (NC) is well known for its high adsorption capacity due to large surface area and pore volume. In recent years, immense research has been focused towards converting the agricultural or lignocellulosic wastes into nanoporous carbon, since this technology not only solves the problem of waste disposal but also converts a potential waste into a valuable product that can be used as an adsorbent for effluent treatment. Palm kernel shell, a lignocellulosic material was selected as the precursor for the preparation of nanoporous carbon in the present investigation. Nanoporous carbons derived from Palm kernel shell (PKS) are materials with improved properties for applications in globally challenging areas in the world today such as water treatment, pollutant, pesticide, energy storage and batteries, catalysis and heavy metal adsorption. In this work, Palm kernel shell (PKS) was chemically activated with phosphoric acid (H_3PO_4) and the effect of temperature and impregnation ratio was investigated. At medium temperature (500 °C), impregnation ratio of 100% H_3PO_4, and carbonization time of 1 hour, nanoporous carbon with a surface area of 1280 $m^2\ g^{-1}$ was achieved under ideal conditions. At various parameters, the surface structure, morphology, surface area, functional group, and thermal stability were investigated. This confirmatively showed that nanoporous carbon possessed a tremendous aptitude for various applications. Nanoporous carbon produced at 500 °C temperature (NC500) for 1 hr was most suitable for the adsorption of Hg(II) under the influences of pH, adsorbent dosage, initial concentration and contact time. The Freundlich model fit the adsorption isotherm best and was fitted with a pseudo-second order kinetic model. While it's maximum Hg(II) adsorption capacity was 55.3 mg/g. The treatment of NC500 with molecularly imprinted polymer incorporated with nanoporous carbon (NC@MIP) and cobalt ferrite nanoparticle (NC@$CoFe_2O_4$ composite) were successfully synthesized, that brought an increase of carboxylic and amine groups on the surface of the NC500 that enhanced the adsorption of mercury. This was confirmed by the various characterizations such as XRD, FESEM, BET, FTIR, VSM and TGA. Batch adsorption was carried out at optimum experimental conditions of 0.3 g, 30 mg/L Hg(II), pH 4, 25 °C for NC500 and NC@MIP, and 0.3 g, 30 mg/L Hg(II), pH 3, 40 °C for NC@$CoFe_2O_4$ composite, demonstrating that Hg(II) removal was highly dependent on the adsorption parameters (dosage, contact time, solution pH, initial ion concentration and temperature). The treated nanoporous carbons had the highest mercury adsorption efficiency. The highest adsorption efficiency of NC@MIP for removing Hg(II) from aqueous solution at room temperature, pH 4 is 116 mg/g when the initial concentration of Hg(II) is 30 mg/L. Conversely, the synthesized nanomaterial NC@$CoFe_2O_4$ composite has saturation magnetization of 33.650 emu/g and obtained the maximum adsorption efficiency of 232.56 mg Hg(II)/g at a pH of 3, when the initial concentration of Hg(II) is 30 mg/L. The adsorption equilibrium data was well explained by Freundlich isotherm and isotherm parameters suggested that the adsorption of Hg(II) on the prepared NC@MIP and NC@$CoFe_2O_4$ composite is chemisorption adsorption. The adsorption of Hg(II) followed pseudo-second-order kinetic for the NC@MIP and NC@$CoFe_2O_4$ composite, while the thermodynamic parameters indicate that the enthalpy, entropy, and Gibbs free energy values show that the adsorption is compatible with spontaneous, favorable, and endothermic reactions. As a result, the synthesized composites can be used as an adsorbent with excellent performance in the field of mercury removal.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

SINTESIS DAN APLIKASI KARBON NANO POROS DENGAN KOMPOSIT FERIT KOBALT DAN POLIMER BERCETAK MOLEKUL UNTUK PENYINGKIRAN MERKURI DARIPADA AIR SISA KUMBAHAN

Oleh

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Pencemaran air telah menjadi cabaran utama kepada saintis alam sekitar disebabkan oleh pembebasan logam berat bertoksik daripada industri. Di antara logam berat, merkuri [Hg(II)] dianggap sebagai sangat toksik kerana sifat karsinogennya dan kesan buruk kepada kesihatan. Sumber pencemaran Hg(II) adalah termasuk daripada efluen industri perlombongan, elektropenyaduran, dan penyamakan kulit. Di antara pelbagai teknologi, kaedah penyingkiran Hg(II) dengan bahan penjerap yang berlainan adalah lebih menjanjikan hasil dan menjimatkan. Di antara pelbagai bahan penjerap yang pernah digunakan, karbon nano poros (NC) amat terkenal dengan kapasiti penjerapannya yang tinggi kerana luas permukaan dan isipadu liang yang besar. Dalam beberapa tahun kebelakangan ini, penyelidikan telah tertumpu ke arah penukaran sisa pertanian atau lignoselulosa kepada karbon nano poros, kerana teknologi ini bukan sahaja mampu menyelesaikan masalah pelupusan sisa buangan, malah dapat menukar sisa buangan menjadi produk bernilai yang boleh digunakan sebagai bahan penjerap untuk rawatan efluen. Tempurung isirung sawit (PKS) yang merupakan suatu bahan lignoselulosa telah dipilih sebagai pelopor untuk penyediaan karbon nano poros (< 2 nm) dalam penyelidikan ini. Karbon nano poros yang dihasilkan daripada tempurung isirung sawit ialah suatu bahan dengan sifat yang dipertingkatkan untuk aplikasi dalam bidang yang mencabar di dunia pada masa ini seperti rawatan air, bahan pencemar, racun perosak, penyimpanan tenaga dan bateri, pemangkinan dan penjerapan logam berat. Dalam penyelidikan ini, tempurung isirung sawit telah diaktifkan secara kimia dengan H_3PO_4 dan kesan pada suhu (500°C) serta nisbah impregnasi telah dikaji. Pada suhu sederhana (500 °C), nisbah impregnasi 100% H_3PO_4, dan masa pengkarbonan selama 1 jam, karbon nano poros dengan luas permukaan 1280 $m^2\ g^{-1}$ berjaya dihasilkan dalam keadaan yang ideal. Pelbagai parameter untuk struktur permukaan, morfologi, luas permukaan, kumpulan berfungsi, dan kestabilan terma juga telah dikaji. Secara keseluruhannya, hasil kajian mengesahkan bahawa karbon nano poros mempunyai kebolehan yang luar biasa dan sesuai untuk pelbagai aplikasi. NC500 didapati paling sesuai untuk penjerapan Hg(II) di bawah pengaruh pH, dos penjerap, kepekatan awal dan masa sentuhan. Model Freundlich paling menepati untuk isoterma penjerapan dan dinilai dengan model kinetik pseudo-tertib kedua. Kapasiti penjerapan maksimum bagi Hg(II) ialah sebanyak 55.3 mg/g. Walau bagaimanapun, rawatan NC500 dengan polimer cetakan molekul (NC@MIP) dan nanopartikel ferit kobalt (NC@$CoFe_2O_4$) berjaya disintesis, yang membawa kepada peningkatan kumpulan berfungsi karboksilik dan amina pada permukaan NC500 yang mempertingkatkan proses penjerapan merkuri. Dapatan ini telah disahkan oleh pelbagai teknik pencirian seperti XRD, FESEM, BET, FTIR, VSM dan TGA. Penjerapan kelompok telah dijalankan pada keadaan eksperimen optimum iaitu pada 0.3 g, 30 mg/L Hg(II), pH 4, 25°C untuk NC500 dan NC@MIP dan 0.3 g, 30 mg/L Hg(II), pH 3, 40°C untuk NC@$CoFe_2O_4$-NP, di mana hasilnya menunjukkan bahawa penyingkiran Hg(II) sangat bergantung pada parameter penjerapan (dos, masa sentuhan, pH larutan, kepekatan awal ion dan suhu). Karbon nanoporous yang dirawat mempunyai tahap kecekapan penjerapan merkuri yang tertinggi. Kecekapan penjerapan tertinggi bagi NC@MIP untuk mengeluarkan Hg(II) daripada larutan akueus pada suhu bilik, dan pH 4 ialah sebanyak 116 mg/g dalam keadaan kepekatan awal Hg(II) sebanyak 30 mg/L. Bahan nano NC@$CoFe_2O_4$ yang disintesis mempunyai kemagnetan tepu 33.650 emu/g dan memperoleh kecekapan penjerapan maksimum sebanyak 232.56 mg Hg(II)/g pada pH 3, dengan kepekatan awal Hg(II) sebanyak 30 mg/L . Data keseimbangan penjerapan telah dijelaskan dengan baik oleh parameter isoterma Freundlich dan parameter yang diperolehi mencadangkan bahawa penjerapan Hg(II) pada penyediaan NC@MIP dan NC@$CoFe_2O_4$ adalah berdasarkan penjerapan bersifat kemisorpsi. Penjerapan Hg(II) adalah berdasarkan model kinetik pseudo-tertib kedua untuk NC@MIP dan NC@$CoFe_2O_4$, manakala parameter termodinamik mencadangkan bahawa nilai tenaga bebas entalpi, entropi, dan Gibbs menunjukkan penjerapan adalah bersesuaian dengan tindak balas spontan yang menggalakkan, dan berdasarkan reaksi endotermik. Hasilnya, komposit yang disintesis boleh digunakan sebagai penjerap dengan prestasi cemerlang dalam bidang penyingkiran merkuri.

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Date: 8 February 2024

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LIST OF ABBREVIATIONS

BET	Brunauer – Emmett - teller
EDX	Energy Dispersive X-ray
FESEM	Field emission scanning electron microscopy
FTIR	Fourier Transform Infrared Spectroscopy
FTIR	Fourier Transform Infrared Spectroscopy
HTC	Hydrothermal carbonization
LHD	Layered double hydroxide
MIP	Molecularly imprinted polymer
NC	Nanoporous Carbon
NC500 10%	Nanoporous carbon synthesized H_3PO_4 10% to precursor
NC500 100%	Nanoporous carbon synthesized H_3PO_4 100% to precursor
NC500 20%	Nanoporous carbon synthesized H_3PO_4 20% to precursor
NC500 30%	Nanoporous carbon synthesized H_3PO_4 30% to precursor
NC500 40%	Nanoporous carbon synthesized H_3PO_4 40% to precursor
NP	Nanoparticle
pH_{pzc}	pH points of zero charge
PKS	Palm Kernel Shell
TGA	Thermogravimetric analysis
UN	United nation
XRD	X-Ray Diffraction

CHAPTER 1

GENERAL INTRODUCTION

1.1 Background of the study

Heavy metals have become one of the world's most serious environmental concerns because their bioaccumulative and biomagnificent properties have rendered them unfriendly and extremely hazardous to aquatic and human health (Schlogl *et al.,* 2023; Awang *et al.,* 2023; Ozsin *et al.,* 2019; Burakov *et al.,* 2018). When heavy metals in water, sediments, air, and other environmental media exceed various recommended limits (Hg = 1µg/L), they cause a variety of diseases such as memory loss, renal and kidney failure, lung damage, and reproductive system malfunction (Demarco *et al.,* 2023; Alloway, 2013). Today, as a consequence of rapid urbanization and industrialization, heavy metals pollution constitutes a grave challenge to the environment and life especially in developing countries where polluted water bodies remain a major source of drinking water for the populace (Ren *et al.,* 2023; Chakraborty *et al.,* 2022; Awual *et al.,* 2008). Heavy metals like mercury, (Hg), lead (Pb), zinc (Zn), copper (Cu), cadmium (Cd) and chromium (Cr) are toxic and potential carcinogens (Arora, 2019; Ma *et al.,* 2018). They are released into the environment especially water bodies by both natural and man-made sources including weathering of rocks, volcanic activities, natural fires, erosion, dyes, fertilizers, pesticides and other industrial products (Da'na, 2017). According to the World Health Organization (WHO), the vast majority of the world's wastewater is released into bodies of water without treatment. According to estimates, if the natural environment continues to degrade and unsustainable pressures are placed on global water resources, 45% of the global GDP, 52% of the world's population, and 40% of global grain production will be affected by 2050 (ESCAP, 2018).

According to literature, Hg(II) is registered as one of the most poisonous metal ions ever discovered and has been responsible for the causes of both acute and chronic toxicity to the central nervous system, kidneys, lung tissues, and reproductive system. This toxic metal ion could be found in the body of human through gastrointestinal absorption, skin contact, or pulmonary inhalation (Arrifano *et al* 2023; Saha *et al.,* 2023; Johs *et al.,* 2019). Thus, Hg(II) circulates in blood stream (cells) and is stored in the liver, kidneys, brain, spleen, and bone, leading to several major health issues such as paralysis, serious intestinal and urinary complications, dysfunction of the central nervous system (Chen *et al.,* 2022). The Agency for Toxic Substances and Disease Registry (ATSDR) ranks mercury as the third most dangerous substance ("ATSDR, Priority list of hazardous substances," 2017), and it can exist in elemental or metallic mercury, organic and inorganic forms (Fabre *et al.,* 2020).

Continuous discharge from natural and industrial activities, mercury contamination has become one of the environmental threats to the human populace and the entire world. Designing a new valuable method with easy implementation and cost effective for the removal of mercury from wastewater remains a challenge. Early research focuses on the removal of mercury using membrane processes, chemical precipitation, extraction, exchange of ions, etc (Kurniawan *et al.,* 2023; Zhang *et al.,* 2021). Numerous papers have been published to date for the removal of mercury from various sources namely; molecularly imprinted polymer (Wu *et al.,* 2022; Metwally *et al.,* 2021; Sharma *et al.,* 2020; Huang *et al.,* 2019; Roushani *et al.,* 2018; Erdem *et al.,* 2018; Yasinzai *et al.,* 2018), graphene oxide (Diagboya *et al.,* 2015; Huang *et al.,* 2018), activated carbon (Lyu *et al.,* 2022; Egirani *et al.,* 2021; Rodriguez *et al.,* 2020; Gai *et al.,* 2019; Abdullah *et al.,* 2018; Abdelouahab – Reddam *et al.,* 2014; Lu *et al.,* 2014), carbon nanotube (Hadavifar *et al.,* 2014), magnetic material (Zhang *et al.,* 2014), metals and metal oxides (Du *et al.,* 2014; Kumar *et at.,* 2014). But recently adsorption has become more important because of its efficiency, simplicity, low cost and usefulness at low concentration. Adsorption is another water treatment technology that is commonly deployed for mercury removal applications. The main advantages of adsorption include no sludge generation, good selectivity for mercury and/or other heavy metals, and flexibility in choice of adsorption media materials**.**

Therefore, application of agricultural waste as an adsorbent for its simple cost and eco – friendliness become the best options for the treatment of mercury from wastewater. At present, Malaysia is the second largest exporter of palm oil cultivating 4.5 million hectares with its agricultural waste amounting to 85.5% (90 x 10^6 tonnes) came from palm oil plantation (Baby *et al.,* 2023; Uchegbulam *et al.,* 2022). One of such is palm kernel shell used to synthesize nanoporous carbon. nanoporous carbon is a carbon-rich material with a solid amorphous structure that has been activated and, thus, has a high porosity with numerous oxygen-containing functional groups, such as carboxylic acids, phenols, carbonyls, and lactones, that has garnered significant interest for energy and environmental applications, such as gas and heavy metal adsorption, separation, energy storage and supercapacitors, medicine, water treatment, sensor, etc (Singh *et al.,* 2021; Benedetti *et al.,* 2018).

Nowadays, several techniques comprising chemical activation as the most common method employed have been introduced to produce high-quality nanoporous carbon because of their superior quality, high porosity, large surface area, and high material yield.

In this study, palm kernel shell was used to synthesize nanoporous carbon using H_3PO_4 as an environmentally friendly, low cost, and readily available adsorbent, and to evaluate whether the modified nanoporous carbon derived from palm kernel shell with molecularly imprinted polymer (MIP) and cobalt ferrite nanoparticle ($CoFe_2O_4$ composite) will have a special impact on Hg(II) adsorption from aqueous solution using batch method. Various characterization methods were used to identify and validate the composites structural, morphological, functional groups, surface area, and thermal stability.

1.2 Problem statement and justification of the study

Continuous release of sewage wastewaters, automobile emission, battery industry, mining activities is of great concern to aquatic pollution which causes severe mental and brain damage. One of the UN Sustainable development goals is the clean water and sanitation by 2030 that includes; sanitation and hygiene services, treatment and reuse of wastewater and ambient water quality, water-use efficiency and scarcity, integrated water resources management and protecting and restoring water-related ecosystems (SDG, 2020).

Mercury is now considered an environmental pollutant of high risk to public health because of its high toxicity and mobility in ecosystems. Exposure to mercury can occur from both natural and artificial sources and it's released into water bodies without any kind of treatment (Beckers *et al.,* 2019; Shan *et al.,* 2019).

However, tackling pollution at its source and treating wastewater protects public health and the environment, mitigates the costly impact of pollution and increases the availability of water resources, in addition to recovering valuable nutrients and water resources, as such there is need for modern techniques to overcome the risk of untreated wastewater containing mercury (Abbas *et al.,* 2018).

Several materials and techniques have been designed for the removal of mercury ions. These methods include chemical precipitation, ion-exchange, electrochemical treatment, reverse osmosis and adsorption techniques (Efome *et al.,* 2018). Generally, the adsorption technique has proved to be one of the most efficient and facile approaches to remove heavy metal ions from aqueous solutions. However, due to reversibility and desorption capabilities, adsorption is regarded as the most effective and economically viable option for the removal of metals from aqueous solution (Shrestha *et al.,* 2021; Masindi and Muedi, 2018). Adsorption has been employed in removing metals such as nickel, lead, cadmium, cobalt, and copper, which consists of passing a liquid stream through a bed of adsorbent media. As the stream flows through, dissolved contaminant molecules attach to the adsorbent media and are thereby separated out from the liquid stream. Over the course of use, the adsorbent media will become saturated and its ability to remove targeted contaminants will decline (Bello *et al.,* 2015; Liu *et al.,* 2013; Wu *et al.,* 2013). To date, different kinds of materials have been applied as adsorbents, including polymers, nanocomposites, activated carbons, clays, graphene materials, and metal oxides like Al_2O_3, TiO_2, SiO_2 (Yu *et al.,* 2018).

Cobalt spinal ferrites ($CoFe_2O_4$) have triggers a lot of acknowledgement from researchers because of strong anisotropy, high coercivity, reasonable saturation magnetization, and good mechanical - chemical stability even at higher temperatures, that can be applied in various technological field such as sensor, recording device, magnetic cards, solar cell, magnetic drug delivery, biomedical, catalysis, and biotechnology (Rafie *et al.,* 2023). Coating modification can improve the dispersibility and stability of $CoFe_2O_4$ particles in water. However, high-efficiency heavy metal removal cannot be achieved solely through coating modification; rather, grafting modification on surface chemical performance of $CoFe_2O_4$ must be further decorated to improve Hg(II) adsorption ability (Zhao *et al.,* 2019). Therefore, many researchers used grafting modification to enhance the Hg(II) adsorption efficiency.

MIPs are highly selective adsorbent substances that offer a promising method to quantify and monitor emerging pollutants in complex matrices. MIPs are composed of synthetic materials with pores or cavities that are designed to hold on to a particular target molecule (Rahim *et al.,* 2023). Their low cost, ease of preparation, reversible adsorption, desorption, and stability make them suitable for the high selective extraction of various environmental pollutants from aqueous and gaseous samples (Villarreal-Lucio *et al.,* 2022).

Though most adsorbents show individual properties such as large surface area, adjustable surface functional groups, feasible regeneration, environmental harmlessness and degradability, with controlled design methods, a combination of these properties can be obtained in a composite material making such material more durable and suitable for mercury adsorption. Also, there is also the need for proper understanding of the adsorption process and the development of very selective adsorbents.

The availability of a range of durable and selective advanced materials of nanoporous carbon and nanocomposites for removal of mercury from contaminated water in developing countries is important in meeting the water needs of people living in such areas and would contribute greatly towards meeting the 2030 target of the UN SDGs. In this regard, this research is significant because it would provide alternative composite materials for fast, robust, efficient and selective mercury removal from contaminated water. It would also enable a detailed understanding of the adsorption mechanism and desorption process facilitating the design of more durable adsorbent materials.

Designing a new valuable method with easy implementation and cost effective for the removal of Hg(II) from wastewater remains a challenge. In this work, we show the incorporation of MIP and $CoFe_2O_4$ with nanoporous carbon to console the effect of wastewater contamination and the palm-kernel shell waste. By keeping in view of the advantages of both MIPs, NCs and cobalt spinal ferrite, the present study investigates the Hg(II) adsorption efficacy of MIPs/NC and NC@$CoFe_2O_4$ nanocomposite from aqueous samples which has been tested for adsorptive removal of Hg(II) from aqueous solution by using batch method. The formed MIPs/NC and NC@$CoFe_2O_4$ nanocomposite has been thoroughly characterized to investigate the morphological, functional groups, surface area, and thermal stability. Further, the tests of efficacy from the prepared nanocomposite proved that the advantages of this work is higher adsorption efficiency and remarkable selection towards Hg(II) ions.

1.3 Research aim and objectives

The aim of this research is to investigate the performance of Hg(II) adsorption by nanoporous carbon derived from palm kernel shell using phosphoric acid. The research study had the following objectives to achieve the goal:

1. To prepare nanoporous carbon derived from PKS and improve the adsorption efficiency of the nanoporous carbon with molecularly imprinted polymer (MIP) and cobalt ferrite nanoparticle ($CoFe_2O_4$).

2. To characterize the structural (XRD), morphological (FESEM), functional groups (FTIR), surface area (BET), and thermal stability (TGA) of the NC, NC@MIP and magnetization (VSM) for (NC@$CoFe_2O_4$) composites.

3. To study batch adsorption of Hg(II) in an aqueous solution using modified nanoporous carbon incorporated with molecularly imprinted polymer (NC@MIP) and cobalt ferrite composite (NC@$CoFe_2O_4$) under various conditions such as adsorbent dosage, solution pH, initial Hg(II) concentration, contact time and reaction temperature.

4. To investigate the result data for the adsorption of Hg(II) on composite materials using kinetic models, adsorption isotherms and thermodynamic parameters.

5. To apply the synthesized altered composites for the removal Hg(II) from the condensate in the oil and gas industry using optimized condition during batch method.

1.4 Scope and limitation

This research focused on the synthesis of five different types of adsorbents derived from palm kernel shell: NC500 100%, NC500 10%, NC500 20%, NC500 30%, and NC500 40%. The best adsorbent was chosen and then modified with other categories of adsorbents that were developed i.e molecularly imprinted polymer (NC@MIP) and cobalt ferrite nanoparticles (NC@$CoFe_2O_4$) composite before being used in a batch method (synthetic and real sample) for Hg(II) adsorption. Reusability and competitive studies were not performed on the composites, advocating for further enhanced reseach looking at the toxicity of the Hg(II) ion. Fourier Transform Infrared (FTIR) spectroscopy, the Brunauer-Emmett-Teller (BET) method, Energy Dispersive X-ray (EDX) analysis, Field Emission Scanning Electron Microscopy (FESEM), and the point of zero charges were used to determine the physicochemical properties of nanoporous carbon and modified composites (pH_{pzc}). However, to evaluate the adsorption capacity and mechanism, the adsorption experimental data were fitted to the Langmuir and Freundlich adsorption isotherm models, as well as the pseudo-first and pseudo-second kinetic orders. The Van't Hoff plot was also used to determine the adsorption thermodynamics data. Finally, the samples were tested on the real wastewater to ascertain its removal efficiency.

1.5 Thesis outline

This thesis consisted of five chapters. Chapter one described the general introduction, background of the study, problem statements, justification, research objective, the scope of the study. Chapter two comprises the related literature reviews. Chapter three consists of description of materials and equipment used, the method employed for the synthesis and alteration of nanoporous carbon and its characterization, adsorption experiment, and data analysis. Chapter four presents the data obtained and the results discussion in the current study. Chapter five concludes the research findings, future research work and possible recommendation.

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