UNIVERSITI TEKNOLOGI MARA

DENDROCALAMUS ASPER AS ACTIVATED CARBON FOR AMMONIACAL NITROGEN ADSORPTION FOR WASTEWATER TREATMENT

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***DENDROCALAMUS ASPER* AS ACTIVATED CARBON FOR AMMONIACAL NITROGEN ADSORPTION FOR WASTEWATER TREATMENT**

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This Final Year Report Project entitled **“*Dendrocalamus asper* as Activated Carbon for Ammoniacal Nitrogen Adsorption for Wastewater Treatment”** was submitted by Nur Shafiqah Binti Samsudin, in partial fulfilment of the requirement for Degree of Bachelor of Science (Hons.) Chemistry with Management, in the Faculty of Applied Sciences, and was approved by

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ABSTRACT

***DENDROCALAMUS ASPER* AS ACTIVATED CARBON FOR AMMONIACAL NITROGEN ADSORPTION FOR WASTEWATER TREATMENT**

Bamboo biochar is a potential material used in wastewater flocculation as well as coagulation. Carbonization and biochar modification using a furnace was used to create bamboo activated carbon, which was subsequently converted by chemical activation. The objectives of this study are to evaluate the optimum effect of mass sample dosage of *Dendrocalamus asper* activated carbon on removal efficiency and adsorption in capacity, Q_e (mg/g) of ammoniacal nitrogen as well as to characterize *Dendrocalamus asper* activated carbon surface functional group using FTIR. The bamboo had been divided into upper and lower nodes, then impregnated with potassium hydroxide 5:1 ratio and oven-dried at 100°C overnight. carbonized at 500°C for 2 hours in a furnace. Then, carbonized at 500°C for 2 hours in a furnace. The results of the ammoniacal nitrogen adsorption capacity revealed that the best contact time for the batch experiment in this study is 143 minutes after 300 minutes of agitation. Mass dosages of 0.005 g, 0.01 g, and 0.05 g were studied. The adsorption capacity of treated biochar decreased with increasing dosage, causing aggregation and reduced absorbed area. Low biochar dosage led to larger particle distances, allowing more ammonium ion aggregation and effective ion exchange. Increased biochar dosage allowed more adsorption sites, potentially increasing removal efficiency and ion exchange sites. High adsorbent concentration protected the perimeter, lowering adsorption capacity. Therefore, the treated biochar dosage of 0.0082 g was determined for the experiment as well the untreated biochar dosage of 0.0082 g was determined in this study. In addition, the FTIR spectrum characterization of bamboo biochar before and after treatment that the impact the surface of functional groups after treated. The FTIR spectrum of biochar-ammoniacal nitrogen shows weak broad adsorption peaks at 1370.12 cm^{-1} and 1558.67 cm^{-1} for upper treatment, indicating stretching of O-H alcohols and aromatic rings. A strong peak at 958.27 cm-1 may indicate the presence of C=C alkene. A weak broad, intense adsorption peak at 705.20 cm-^{1} indicates the bending of the alkene group. The medium bend within the region of 1444.55 cm^{-1} aromatic ring for lower treatment is due to C-H bent adsorption. The best mass dosage for this study is at 0.0082 g where the percentage removal for treated is at 92.2% meanwhile untreated is at 89.32%. Besides, the adsorption capacity for treated and untreated are the same; 450 mg/g.

ABSTRAK

DENDROCALAMUS ASPER SEBAGAI KARBON AKTIF UNTUK PENYERAPAN NITROGEN AMMONIA UNTUK RAWATAN AIR KUMBAHAN

Buluh biochar adalah bahan yang berpotensi digunakan dalam pemberbukuan air sisa serta koagulasi. Pengkarbonan dan pengubahsuaian biochar menggunakan relau untuk mencipta karbon teraktif buluh, yang kemudiannya ditukarkan oleh pengaktifan kimia. Objektif kajian ini adalah untuk menilai kesan optimum dos sampel jisim karbon teraktif *Dendrocalamus asper* terhadap kecekapan penyingkiran dan kapasiti penjerapan, Qe (mg/g) nitrogen ammonia serta untuk mencirikan kumpulan berfungsi permukaan karbon teraktif *Dendrocalamus asper* menggunakan FTIR. Buluh telah dibahagikan kepada nod atas dan bawah, kemudian impregnasi kalium hidroksida nisbah 5:1 dan dikeringkan dengan ketuhar pada suhu 100°C semalaman. Kemudian, dikarbonkan pada 500°C selama 2 jam dalam relau. Keputusan kapasiti penjerapan nitrogen ammoniakal mendedahkan bahawa masa sentuhan terbaik untuk eksperimen kelompok dalam kajian ini ialah 143 minit selepas 300 minit pengadukan. Dos jisim 0.005 g, 0.01 g, dan 0.05 g telah disemak semula. Kapasiti penjerapan biochar yang dirawat berkurangan dengan peningkatan dos, menyebabkan pengagregatan dan mengurangkan kawasan yang diserap. Dos biochar yang rendah membawa kepada jarak zarah yang lebih besar, membolehkan lebih banyak pengagregatan ion ammonium dan pertukaran ion yang berkesan. Peningkatan dos biochar membolehkan lebih banyak tapak penjerapan, berpotensi meningkatkan kecekapan penyingkiran dan tapak pertukaran ion. Kepekatan penjerap yang tinggi melindungi perimeter, mengurangkan kapasiti penjerapan. Oleh itu, dos biochar yang dirawat sebanyak 0.0082 g telah ditentukan untuk eksperimen serta dos biochar yang tidak dirawat sebanyak 0.0082 g telah ditentukan dalam kajian ini. Di samping itu, pencirian spektrum FTIR buluh biochar sebelum dan selepas rawatan yang memberi kesan kepada permukaan kumpulan berfungsi selepas dirawat. Spektrum FTIR bagi nitrogen biochar-ammoniacal menunjukkan puncak penjerapan luas yang lemah pada 1370.12 cm^{-1} dan 1558.67 cm^{-1} untuk rawatan atas, menunjukkan regangan alkohol O-H dan cincin aromatik. Puncak kuat pada 958.27 cm^{-1} mungkin menunjukkan kehadiran C=C alkena. Puncak penjerapan yang luas dan kuat yang lemah pada 705.20 cm^{-1} menunjukkan lenturan kumpulan alkena. Lenturan sederhana dalam lingkungan cincin aromatik 1444.55 cm^{-1} untuk rawatan yang lebih rendah adalah disebabkan oleh penjerapan bengkok C-H. Dos jisim terbaik untuk kajian ini ialah pada 0.0082 g di mana peratusan penyingkiran untuk dirawat adalah pada 92.2% manakala tidak dirawat adalah pada 89.32%. Selain itu,kapasiti penjerapan untuk dirawat dan tidak dirawat adalah sama; 450 mg/g.

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(Nur Shafiqah Binti Samsudin)

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LIST OF ABBREVIATIONS

ATR	:	Attenuated Total Reflection
BET	:	Brunauer-Emmet-Teller analyser
BOD	:	Biological Oxygen Demand
COD	:	Chemical Oxygen Demand
FTIR	:	Fourier-transform Infrared Spectroscopy
KOH	:	Potassium Hydroxide
Q_e	:	Adsorption capacity
SEM	:	Scanning Electron Microscope
TGA	:	Thermogravimetric analyser

CHAPTER 1

INTRODUCTION

1.1 Background of Study

1.1.1 Water Pollution

Water pollution is a critical issue in Malaysia that harms the sustainability of water resources. Along with that, it has an impact on biological plants and organisms, as well as healthcare quality and the economy. The entire amount of water is reduced greatly since the expenses in treating contaminated water is extravagant, while in some circumstances, polluted water is not safe to consume. In addition, water contamination in Malaysia is influenced by both point and non-point sources (Garba *et al.*, 2021). Furthermore, rising population growth and urbanization expansion have led to a constant demand for water consumption while also affecting Malaysia's levels of water pollution. Lakes and reservoirs deliver water for the household, industrial, agriculture, hydroelectric, navigation, and recreational purposes. As a result, wastewater treatment is critical. Bamboo charcoal is an alternative for effective wastewater treatment. For instance, considering rivers contribute 98% of all water, river pollution is a serious issue, with progressively rivers being contaminated (Rout *et al.*, 2021). Continuous river contamination will minimize water resources as time progressed with the activities. It will have a substantial impact on the national objective to become a fully developed nation unless considerable steps are taken to improve the quality of our river water. Contamination from both point and non-point sources endanger our ecosystems. The primary point sources of pollution are waste treatment plants, agriculture, industries, sulphur or drainage system from business and residential properties, and pig farms (National Geographic, 2021). Non-point source risk from exposure to water pollution is caused by secondary sources such as property use, land-use changes, and contaminated runoff from agricultural regions that drain into a river (Bashir *et al.,* 2020).

1.1.2 Agricultural Water Pollution

Firstly, agricultural water pollution. Water is acknowledged as the most crucial resource for global sustainable development. It is necessary not only for agriculture, industry, and economic processes, but it is also the most significant component of the environment, which has a significant influence on health and environmental conservation (WWF, 2019). Agricultural water contamination is well-known phenomenon across the world. Water pollution from unsustainable farming methods poses a severe danger to both human health and the planet's ecosystems, a concern that is frequently embraced by governments and local farmers (United Nations, 2018). Agriculture is the most frequently observed source of water pollution in many nations today, whether in cities or industry, and nitrate from farming is the most widely used chemical contamination identified in groundwater aquifers globally (Mateo-Sagasta *et al.,* 2017). Furthermore, population centres and sectors of the economy are very well known as sources of pollution. However, current studies data prove that agriculture is one of the going to lead causes of water pollution worldwide, with massive volumes of agrochemicals, nutrients, organic material, chemical entities for synthetic drugs, sediments, saline drainage causing soil salinity and alkalinization, microplastics, and pathogens are been discharged. Water pollution is caused by a decrease in flow in bodies of water, which is mainly influenced by agricultural requirements for crop irrigation (Kumar *et al.,* 2021). Agriculture is indeed the manipulation of land, water, and natural resource to create improved variants of specific plant and animal species in larger quantities than would occur naturally. Therefore, agriculture has a massive effect on water quality (Camara *et al.,* 2019). Agriculture is generally recognized to be the single greatest consumer of freshwater resources, contributing to 70% of all surface water supply globally (FAO, 2021). Additionally, except for evaporation and transpiration, agricultural water can be reused again to surface water or groundwater. Agriculture, on the other hand, acted as both source and a sufferer of water contamination.

1.1.3 Water Treatment Importance

Next, the importance of water treatment. Access to clean water, sanitation, and hygiene is a basic human right, yet billions of individuals all over the world face major challenges in receiving the most basic services daily (Paul, 2022). Ensuring and maintaining an appropriate quantity of water has been an important aspect of human settlement development (World Bank Group Water Global Practice, 2019). World Wildlife Fund (2022) also stated that the very first developments were largely focused on the amount of accessible water. Matter of fact, expanding population has placed an additional burden on a few high-quality surface supplies, and pollution of water with residential, agricultural, and industrial water has caused a degradation in water quality in various other sources (Camara *et al.,* 2019). Also, while establishing a water supply, the condition of the water source cannot be disregarded. In reality, almost all sources of water must be treated before being transported (Crittenden *et al.,* 2016). If wastewater is not adequately handled, both the ecosystem and people's health might be at risk. These implications can include damage to fish and animal populations, oxygen depletion, beach closures as well as other limits on recreational water usage, limitations on fish and shellfish harvesting, and drinking water pollution. The ultimate focus of wastewater treatment is to eliminate as many suspended particles as possible before returning the leftover water, known as effluent, to the ecosystem. As solid matter decays, it consumes oxygen, which is required for the plants and animals that live in the waters. Water treatment is the procedure of water to reach water quality that exceeds specific goals or criteria established by the final consumer or society through its regulatory authorities (Clements, 2022).

1.1.4 Water Treatment Process

The Kuching Water Supply System was the first groundwater system in Sarawak and the water quality in the state of Sarawak is provided by Kuching Water Board, Sibu Water Board, LAKU Management Sdn. Bhd.

and Public Works Department Sarawak (Mahyan *et al.,* 2016). KWB provides water to Kuching City regions, SWB to Sibu town, and LAKU Management Sdn. Bhd. to Bintulu, Miri, and Limbang (Mahyan *et al.,* 2016). Besides, Jabatan Kerja Raya (JKR) Sarawak continues to carry out the duty and obligations of developing and controlling water sources in other regions of Sarawak, particularly in rural areas (Mahyan *et al.,* 2016). The Public Works Department Sarawak, throughout its Water Supply Branch, is tasked with providing treated water to locations in Sarawak when Water Supply Agencies do not supply treated water (Mahyan *et al.,* 2016).

Water treatment technology has a rich history of empirical and scientific breakthroughs, as well as problems addressed and overcome (Crittenden *et al.,* 2016). The conventional method of establishing water quality indexes in use uses a mathematical approach that is not necessarily exact. Standard indices are utilized as comprehensive evaluation tools by regulatory authorities dealing with pollution abatement concerns at an early stage (Izah *et al.,* 2021).

Clean water is important for fisheries because it supports plants and animals that dwell in the water. Besides that, for our health concerns, water might contain illness if not adequately cleansed. Water Science School (2018) also stated that water activities such as swimming, fishing, boating, and picnics attract visitors. Therefore, biochar is utilized at various stages of wastewater treatment to boost treatment efficiency and produce valuation results. The process of adsorption, buffering, and immobilization of microbial cells might control biochar employment in wastewater treatment (Pokharel *et al.,* 2020). When applied to treated effluents, appropriately adjusted biochar may efficiently adsorb nutrients such as nitrogen and phosphorus, and can then be utilized as a nutrient-enriched material for soil rehabilitation (Pokharel *et al.,* 2020). When utilized in the activated sludge treatment process, biochar might improve sludge treatment and settling via the adsorption of inhibitors and hazardous chemicals or offer a surface for microbial immobilization (Pokharel *et al.,* 2020). The introduction of biochar towards the biological system may ultimately aid to increase the biosolid's soil stabilization qualities as well. As interest in biochar in soil applications develops, its use in wastewater treatment might broaden the value chain and generate further economic benefits (Gupta *et al.,* 2022). The next part will describe the importance of biochar for multiple applications in wastewater treatment plant and the process of wastewater treatment:

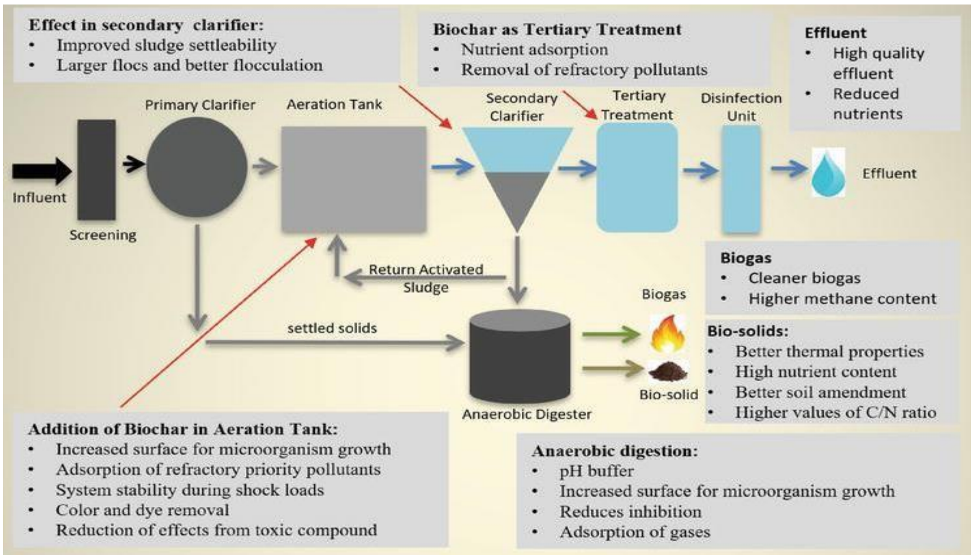

Figure 1.1 Biochar is used in many phases of wastewater treatment (Pokharel *et al.*, 2020).

1.1.5 Biochar for Wastewater Treatment

Bamboo biochar is recommended as a new method to use as wastewater treatment. Nutrients, organic matter, and metals are common contaminants that cause severe deterioration of the water quality when the concentration reaches specified limits. Water quality degradation has been addressed by utilizing a variety of treatment techniques. As a result of its high specific surface area and porosity, large adsorption capacity, and easy production technique, biochar is regarded as an efficient and cost-effective adsorbent (Rodriguez *et al.*, 2019). Biochar is a black charcoal substance with fine grains. It differs from typical charcoal essentially in that it is designated for use as a soil amendment rather than as a fuel for heating or cooking (Fetter *et al.*, 2022).

1.1.6 Biochar Environmental Impact

Biochar has a lower environmental impact than activated carbon and may be more cost-effective in terms of functionality (Ambaye *et al.*, 2021). Recently, there has been significant growth in the investigation of the adsorption of contaminants and the purification of sewage using biochar (Kamarudin *et al.*, 2021). Since it can offer sufficient operating space for microorganisms, it can absorb, fix, and eliminate heavy metal pesticides and petroleum pollutants, minimizing pollution absorption and purifying water quality (Xie *et al.*, 2021). Other than that, biochar has a large surface area, physical features that enables it to easily connect with other substances, and a very strong structure that allows it to survive for a long time (Yaashikaa *et al.,* 2020). These qualities have led to the assumption that biochar has several agricultural and water quality benefits. These pros include improved soil moisture retention. This is beneficial to plant development when rainfall is minimal. This is beneficial to water quality since it minimizes runoff. It can also improve soil nutrient retention. This is beneficial to plant development in low-nutrient soils (Mohubedu *et al.,* 2019). This improves water quality by reducing nitrogen leaching into groundwater and discharging into surface water (Craswell, 2021). Therefore, biochar can stabilize carbon storage (Gross *et al.,* 2021). It offers a technique for sequestering carbon from different organic wastes rather than releasing carbon into the atmosphere through regular burning (Kowalska *et al.,* 2020). Furthermore, biochar has a highly adsorbent surface with many functional groups. This means it can absorb and filter contaminants such as metals from water. As a result, biochar has also been employed successfully in the wastewater treatment process.

1.1.7 Advantages of Biochar

The advantages of bamboo biochar. Biochar is a carbon-containing stable solid that may be preserved in soil for many long periods. Biochar's carbon is resistant to decay and can preserve carbon in soils for hundreds to thousands of years. It is a good habitant for microorganisms in the soil, enhances the bioavailability, and acts as a fantastic reservoir for water nutrients and contaminants that are projected to take hundreds of years to biodegrade (Osman *et al.,* 2022). Bamboo charcoal has numerous benefits.

Among the benefits of bamboo, biochar is its high porosity, which is about five times more than that of hardwood charcoal, and its absorption efficiency, which is 10 times better (Handa, 2022). Additionally, its high carbon content implies that it be used as a large pool of carbon storage in the soil in cooperation with soil development (Hernandez–mena *et al.,* 2014). Also, because of its high capacity to absorb and hold moisture, soil nutrients, fertilizers, and soil microbes, bamboo biochar can significantly raise agricultural production by 50-70%, neutralize acidic soils, and repair damaged soil (Panwar *et al.,* 2019). Its advantages include the ability to increase plant development, soil-microorganism ecology, soil water management, and so on (Handa, 2022). Besides that, bamboo biochar absorbs unpleasant odours, filters the air, regulates air humidity, absorbs electromagnetic radiation, boosts human health and the ability to absorb unwanted odours (Gupta *et al.,* 2022). Aside from that, bamboo biochar utilized in the production of activated carbon (Khuong *et al.,* 2021). Thus, activated carbon is a kind of carbon that has a large surface area and a high degree of microporosity, making it useful for air, water, and wastewater treatment (Zhang *et al.,* 2021).

1.2 Problem Statement

Water resources, groundwater, people's health, and the ecosystem are all impacted by wastewater pollution in developing country like Malaysia (Afroz *et al.,* 2014). Malaysia's river water quality is deteriorating daily. Wastewater effluent from the general population is frequently coloured and contains chemicals that require adequate treatment before being released into the environment, such as a river or lake. Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), ammonium nitrogen, and colour discharge are undesirable under Malaysian environmental regulations (Lokman *et al.*, 2021). Polluted water, whether the consequence of human activity or natural causes has impacted the lives of ordinary people.

As an outcome, wastewater management is presently an obstacle in developing countries around the world, including Kuching, Sarawak, and Borneo Island's metropolitan areas. Without sufficient treatment, insufficiently processed septic tank wastewater and greywater are released directly into natural rivers, posing serious threats to human health, economic output, the sustainability of ambient freshwater supplies, and ecosystems (Kuok *et al.*, 2022). Aside from treating wastewater, numerous techniques have been recognized for helping to improve river water quality, which include preventing pollution, trying to eliminate dumping and minimizing the release of hazardous chemicals and materials, dividing the proportion of untreated wastewater, and greatly increasing recycling and safe reuse globally (Kuok *et al.*, 2022).

Wastewater treatment is crucial in today's world for safeguarding the river environment and guaranteeing sustainable life. The initiatives necessary to attain sustainable living would create a greater financial burden on low- and lower-middle-income nations, placing them at a competitive disadvantage when compared to high- and upper-middle-income countries (Gallego-Schmid and Tarpani, 2019). To ensure environmental preservation, it is critical to identify the appropriate solution to this problem caused by that component.

Therefore, bamboo, which is considered a renewable, minimal, and readily accessible material, is appropriate to be utilized as an adsorbent (Militao *et al.,* 2021). In latest years, there has been an increase in the use of bamboo as a feedstock for wastewater treatment (Lamaming *et al.,* 2022). Bamboo-derived adsorbents, such as bamboo-activated carbon and bamboo biochar, have been created by experts (Kuti *et al.,* 2018). There are several carbon sources obtained from agricultural waste, but bamboo-based adsorbents stand out owing to their outstanding surface area to mass ratio, which enables them to absorb a diverse spectrum of materials, compounds, metals, moisture, aromas, and even electromagnetic radiation (Isa *et al.,* 2017). Adsorption is now regarded as a long-term, adaptable, and successful method for eliminating different impurities and pollution from water and wastewater treatment (Lamaming *et al.,* 2022). To enhance adsorption efficiency, a good adsorbent should have a porous structure with a large surface area, and the time needed to achieve adsorption equilibrium should be short so that pollutants may be eliminated quicker.

1.3 Significance of Study

The increasing population has led to a higher demand for commodities, which has resulted in fast industrialization, and the expansion in industrial setups has resulted in a higher output of industrial pollution (Ahmed *et al.*, 2021). These wastewaters impact negatively the ecosystem by contaminating the water, air, and land. The kind of industry determines the quality and quantity of wastewater produced: it might contain non-biodegradable trash such as heavy metals, pesticides, plastic, and so on, as well as biodegradable compounds (Ahmed *et al.*, 2021).

Considering industrial wastewater can be poisonous, corrosive, radioactive, or ignitable, releasing it into water bodies can have disastrous environmental and health consequences if not properly treated and managed (Ahmed *et al.*, 2021). Over the last decade, researchers have conducted an extensive study on the use of biochar to remove pollutants from aqueous solutions (Wang *et al.*, 2020).

Biochar, a new sorbent with considerable promise, has demonstrated major benefits such as a wide range of feedstock sources, a simple preparation procedure, and good surface and structural qualities (Wang *et al.*, 2020). This research gives an overview of current achievements in biochar application in water and wastewater treatment, along with a brief explanation of the sorption processes involved in pollutant removal as well as biochar modification approaches. Moreover, environmental issues about biochar are raised, and future research objectives are proposed to encourage the use of biochar in effective water and wastewater treatment.

1.4 Objectives of Study

The objectives of this study are:

1. To evaluate the optimum effect of mass sample dosage of *Dendrocalamus asper* activated carbon on removal efficiency (%) and adsorption capacity, Q_e (mg/g) of Ammoniacal Nitrogen.
2. To characterize *Dendrocalamus asper* activated carbon surface functional group using Fourier-transform infrared spectroscopy (FTIR).

CHAPTER 2

LITERATURE REVIEW

2.1 Bamboo Biochar

2.1.1 Bamboo

A life cycle evaluation of bamboo is recommended to investigate the environmental implications of bamboo as a construction material (Amatosa *et al.,* 2019). The findings of this interpretation showed that, in some situations, bamboo has a high "factor 20" environmental effect, putting a 20-fold lower stress on the environment than some alternatives (Van *et al.*, 2006). Wood and bamboo have recently gained renown in the green engineering technology industry due to their environmentally good potential characteristics: they are biodegradable, confine carbon from the atmosphere, are low in combined energy, and produce less pollution during development than concrete or steel (Falk *et al.,* 2019). According to the researcher's understanding, bamboo is a possible charcoal feedstock that is widely farmed in the Asia-Pacific area, notably Japan (Hien *et al.*, 2021). Currently, roughly 36.8 million hectares of bamboo are grown in tropical, subtropical, and temperate climates (Xiu *et al.,* 2020). Furthermore, because it is easy to produce and has a range of valuable features, bamboo is one of the forest product commodities that have the potential to be utilized as a wood substitute (Maulana *et al.*, 2022). Bamboo possesses physiological qualities that make it ideal for communal use, specifically in agriculture and forestry (Sinyo *et al.,* 2017). As a consequence, Maulana *et al.,* (2022) said that bamboo might be used in several ways as one of the proposed raw materials for biochar production.

2.1.2 Biochar

Biochar may be produced from biomass waste, which is both environmentally beneficial and cost-effective. Biochar sources suitable for manufacturing include crop wastes (Zhu, 2021). Nowadays, a huge quantity of agricultural, municipal, and forestry biomass is burnt or decomposed, releasing CO_2 and CH_4 into the atmosphere and potentially polluting local groundwater and surface water, which is a major issue with livestock manure (Zhu, 2021). As a result, using these materials to manufacture biochar can not only eliminate it from the pollution cycle but also produce biochar as a by-product of biomass energy generation (Zhu, 2021). Furthermore, biochar is high in carbon, which is influenced by the type of biomass used, such as bamboo, as well as the manufacturing method. Biochar's physical properties are determined by the biomass feedstock and many process parameters, which effectively define the application's purpose (Janu *et al.*, 2021). Further, Maulana *et al.*, (2022) noted that the procedure utilized to manufacture biochar has a considerable influence on the ratio of biochar produced as well as the qualities of the resulting biochar.

Biochar usually prepared from biomass at temperatures below 700°C under anaerobic circumstances, whereas activated carbon is generated from prepared carbon at temperatures exceeding 700°C (e.g., 800-1000 °C) using activated gas such as steam, flue gas, and so forth (Liu et al., 2019). As a result, their qualities change depending on the surface (physical) and functional group (chemical). Activated carbon tends to have a greater specific surface, but biochar contains numerous functional groups.

Following that, biochar may be thought of as a substance that improves environmental protection by minimizing nutrient leaching, lowering greenhouse gas emissions, sequestering carbon, boosting soil fertility, and lowering heavy metal pollution in water and soil (Hien *et al.*, 2021). Nevertheless, bamboo is a versatile crop, with all of the plant's components being utilized in a variety of sectors (Van *et al.,* 2018). Yet, the fast development of bamboo forests has dwarfed other plant species, resulting in monoculture forests, which contribute to the loss of biodiversity and soil nutrition while also destroying soil physical structure (Xu *et al.*, 2020). However, Mohammadi *et al.,* (2020) suggested that applying biochar to semiarid farms can continuously improve soil carbon content and lower CO_2 emissions. Hence, biochar is a stable type of charcoal formed by high-temperature, low-oxygen burning. By optimizing the pace at which organic matter is introduced and the rate at which it decomposes and returns to the environment as CO_2, biochar can store carbon for estimation of 100 years in soil (Maulana *et al.*, 2021).

2.1.3 Pyrolysis

In recent times, there has been a rise in awareness of the production of biochar as a useful commodity derived from biomass valorization by pyrolysis (Kamali *et al.*, 2021). Worldwide worries about water pollution and the challenges connected with the production and release of massive volumes of industrial effluents, on the other hand, have encouraged research efforts to investigate efficient and cost-effective solutions to these problems (Arslanoğlu *et al.*, 2020). As a result, biochar has been proposed as a possible alternative for dealing with wastewater contaminated with both traditional and emergent pollutants (Kamali *et al.*, 2021).

2.1.4 Properties of Biochar

Biochar is produced by pyrolyzing biomass. Pyrolysis is the most ancient known form of biomass thermal processing (Tomczyk *et al.*, 2020). The determination of acceptable circumstances for generating char with the necessary qualities thus necessitates the quantitative and qualitative understanding of interdependence and affecting variables (Weber *et al.*, 2018). Biochar is created by the processes of combustion or pyrolysis, which heat biomass in the absence of oxygen. Because micropores form during the pyrolysis process, biochar has a huge microscopic surface area and may be employed as a soil amendment, nutrient retention, pollutant adsorption, and ion exchange capacity (Tomczyk *et al.*, 2020). As an outcome, bamboo biochar includes carbon-rich residues (65-90%), is fine-grained and porous, appears black, and is a stable form of carbon material.

Bamboo biochar has remarkable surface characteristics that are similar to activated carbon and function as a moderate adsorbent (Hornaday, 2022). Therefore, some studies have reviewed and examined biochar breakdown and characterization methodologies, as well as their usage in pollutant or contaminant removal (Amaalina *et al.*, 2022). Numerous methods for changing biochar to generate unique structures and surface characteristics have been explored based on the parameters impacting its properties to increase its remediation efficacy and environmental benefit (Lamaming *et al.*, 2022). Table 2.1 shows the biochar generated from bamboo has an adsorption capacity for contaminant or pollutant removal.

Table 2.1 Adsorption capacity of biochar generated from for contaminant or pollutant removal.

Type of Biochar	Pyrolysis Condition	Adsorbate	Parameters (Concentration, Temperature, Time)	pH	Adsorption Capacity (mg/g)	References
Unmodified	500ºC	Fluoroquinolone antibiotics	500 mg/L, 25ºC, 96 h	3-10	45.88	Wang *et al.*, 2015
Ball milled	480ºC, 5ºC/min, 2 h Ball milled (300 rpm, 12 h)	Sulfamethoxazole Sulphapyridine	3-30 mg/L, room temperature, 24 h	6 6	25.70 58.60	Huang *et al.*, 2020
HNO_3 modified	500ºC/700ºC, 3h	Cd^{2+}	100 mg/L, 35ºC, 1.5 h	7	17.29	Tang *et al.*, 2020
Hydrous	370ºC	Ammonium ion	100 mg/L, 20ºC, 12 h	6.5	6.38 mM/g	Fang *et al.*, 2019
Fe modified	600ºC	Nitrogen	8.561-10.618 mg/L (low N) and 16.932-18.774 mg/L (high N), 19.6-25.3ºC, 12-96 h	-	128.40 g	Jia *et al.*, 2020

2.1.5 Bamboo Biochar from *Dendrocalamus asper*

Dendrocalamus belongs to the *Bambuseae family*, which has roughly 35 species (Mustafa *et al.*, 2021). *Dendrocalamus asper*, sometimes known as sweet bamboo, is a versatile tropical clumping bamboo with a high economic value (Mustafa *et al.*, 2021). *Dendrocalamus asper*, commonly known as rough bamboo, black bamboo, or huge bamboo, and has moderately thick walls (Hossain *et al.*, 2018).

Table 2.1.1 Physical Characteristics *Dendrocalamus asper* Bamboo Plant (Hossain *et al.*, 2018)

Height	20-30 m
Diameter	8-20 cm
Internodes	20-45 cm long

The origins of *Dendrocalamus asper* are unknown, although they are found throughout India and South East Asia, including Thailand, Vietnam, Malaysia, Indonesia, and the Philippines, according to Mustafa *et al.*, (2021). *Dendrocalamus asper* has recently been introduced into several tropical nations, including Ghana, Benin, the Democratic Republic of the Congo, Kenya, and Madagascar. Furthermore, throughout tropical Asia, *Dendrocalamus asper* grows best in humid places with rich, heavy soils, from lowland areas to 1500 m altitude, with an average annual rainfall of around 2400 mm; although, with correct care, it may also thrive in semiarid conditions (Mustafa *et al.*, 2021).

According to Singh *et al.,* (2012), mature stems are utilized to construct furniture, percussion equipment, domestic items, handcraft, and paper, whereas higher internodes are used to build containers and cooking pots. Furthermore, the *Dendrocalamus asper* may be reproduced through the rhizome, stems, and branch cuttings. After the roots have sprouted, the propagules are cultivated in a nursery and then planted in the field before or during the first part of the monsoon season (Mustafa *et al.,* 2021). Aside from that, *Dendrocalamus asper* bamboo is used to make charcoal fuel, pharmaceuticals, and industrial products such as those used to filtrate and cleanse liquids and gases and absorb excess moisture (*Dendrocalamus*, n.d.). Furthermore, *Dendrocalamus asper* bamboo burns hot and cleanly, making it a great replacement for wood charcoal in cooking and barbecuing. It is often offered as ordinary charcoal or briquettes and is made from culms farmed for the purpose as well as trash, such as sawdust (Chongtham & Bisht, 2020). Additionally, *Dendrocalamus asper* bamboo activated charcoal, finely porous and pure charcoal manufactured under regulated circumstances, is mostly derived from *Dendrocalamus asper* bamboo and is utilized in industry for air, gas, and alcohol filtering, chemical and metal purification, excess moisture absorption, and waste treatment (Chongtham & Bisht, 2020).

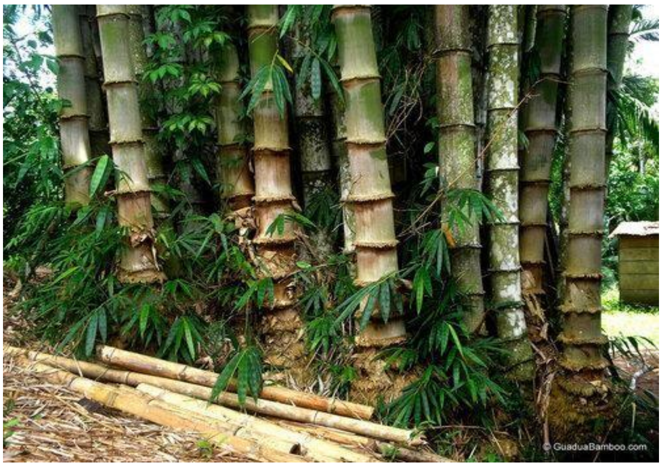

Figure 2.1 *Dendrocalamus Asper* (Schröder, 2021)

2.1.6 Activated Carbon

Islam *et al.,* (2017) stated that activated carbon is the most often used technology due to its benefits of high removal efficiency, ease of operation with fewer technical challenges, minimal capital cost, strong recycling performance, and eco-friendly characteristics. Additionally, adsorption's effectiveness as a technique of water purification is enhanced by its broad compatibility with many types of dyes without the formation of dangerous by-products during the process (Wakkel *et al.*, 2019). While commercial activated carbons with complex activation processes are well-known to be the most commonly used adsorbents for water treatment with high removal efficiency (Islam *et al.,* 2017). The high cost of commercial activated carbons with complex activation processes will restrict the application even although sustainable biomass as precursor will limit the application (Hou *et al.,* 2019). In comparison to the manufacture of activated carbons, biochar was a carbon-enriched solid residue from biomass carbonization in the absence of oxygen, without the need for sophisticated activation methods

(Hou *et al.,* 2019). Because biochar has a net negative charge on its surface due to the dissociation of O-containing functional groups, it can be utilized as a low-cost adsorbent to replace activated carbons in wastewater treatment (Hou *et al.*, 2019). Next, bamboo is a carbon material with the potential to manufacture activated carbon since it is abundant in Indonesia, where there are around 60 distinct species of bamboo (Qanytah *et al.,* 2020). In the liquid and gas phases, activated carbon is a very efficient adsorbent for various organic and inorganic contaminants (Lewoyehu, 2021).

Carbonization is the process in the production of activated carbon. Carbonization is used to increase the carbon content while also developing the original porosity, and bamboo charcoal is the carbonaceous residue left after heating bamboo in the absence of oxygen at temperatures of about 400 °C (Qanytah *et al.*, 2020). The carbonization procedure is critical in the preparation of activated carbon since it determines the impression impact on the finished product. According to Qanytah *et al.*, (2020), it is therefore critical to select the carbonization parameters to produce the required quality of the final activated carbon, and in the carbonization process, many other parameters would change the structure, one of which is carbonization temperature. The physical and chemical nature of the precursor, as well as the activation process, influence the adsorption level and features of activated carbon (Danish and Ahmad, 2018).

Furthermore, the activation process aids in the improvement of pore structure. The residue of the carbonization process is then used as the basic material for the activation stage (Heidarinejad *et al.,* 2020). The charcoal is therefore activated by steam in the same reactor at temperatures ranging from 650ºC to 800ºC. Some of the carbon is oxidized, resulting in the formation of pores. It is critical at this point to maintain continuous activation conditions (Mahanim *et al.,* 2011).

There are two forms of biochar activation for activated carbon production: chemical activation and physical activation. Many studies use physical approaches for biochar activation, which might improve biochar surface structure (Zhang *et al.*, 2020). Physical activations can cause major physical changes in the surface area, pore volume, and pore structures of biochar, which are critical factors for biochar applications. Additionally, Akhil *et al.,* (2021) claimed that physical activation modifies not only the porosity of biochar but also its surface chemical characteristics. The most common physical activations for biochar are steam activation and gas activation.

For chemical activation, to activate biochar chemically, acid, alkali, and oxidation treatments were used, which resulted in a considerable increase in the physicochemical characteristics of biochar. The acid treatment technique has two good outcomes (Tan *et al.,* 2017). The acid treatment may increase the pore characteristics of biochar, such as surface area and porosity, which might be linked to the elimination of contaminants on the surface of biochar by acid (Tan *et al.,* 2017). Next, acid treatment might add or enhance the number of functional groups on the surface of biochar (Tan *et al.,* 2017). According to Tan *et al.,* (2017), two major impacts of alkali treatment occur, including improved pore characteristics and functional groups of biochar. Further, following alkali treatment, O-containing groups can be incorporated into biochar (Yang *et al.*, 2020). The activation of municipal solid waste biochar with a potassium hydroxide solution enhanced the number of functional groups on the surface of activated biochar (Revilla *et al.*, 2020).

2.1.7 Advantages of Activated Carbon

Bamboo-activated carbon (*Dendrocalamus asper*) is a very porous substance with a considerable surface area that is usually applied as an adsorbent (Qanytah *et al.,* 2020). Nevertheless, activated carbon is a nonpolar adsorbent with poor selectivity with polar chemicals and is therefore regarded as economically feasible for absorbing indoor air pollutants at ambient temperature (Wang *et al.*, 2022). Further, Rao *et al.*, (2021) noted that in recent years, enhanced activated carbon-containing metal nanoparticles have been regarded as promising adsorption and oxidation catalytic process because of their improved ability to formaldehyde. Moreover, activated carbon is believed to have a heterogeneous physical and chemical structure, with micro, meso, and macro holes of varying sizes, and its surface indicating non-polar and hydrophobic properties (Palliyarayil *et al.*, 2021).

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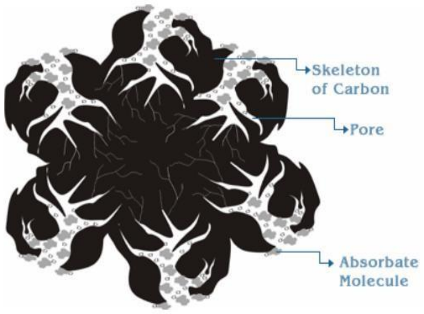

Figure 2.1.1 Structure of activated carbon (Mohammed, 2018).

Besides, the removal of nutrients from wastewater before disposal to natural water bodies is critical because high nutrient loads can induce eutrophication (Kakade *et al.,* 2021). As a result, filtration is a well-established wastewater treatment process (Fundneider *et al.,* 2021). The effectiveness of nutrient removal in filters is determined by the filtering medium utilized. Because of its high surface area and adsorption capacity, activated carbon can improve the performance of the filter medium (Wang *et al.,* 2022).

2.2 Adsorbent from Biomass for Water Treatment

Bamboo is used as a biomass sample in this research. The biomass is divided into four categories: agricultural waste, municipal garbage, industrial waste, forestry residue, and wood. Biomass has long been explored as an adsorbent in wastewater treatment due to its availability, low price, and the existence of many functional groups (Boakye *et al.,* 2022). Due to their short regeneration cycle, efficacy, availability, chemical stability, environmental friendliness, and low price, agricultural waste can be employed as an adsorbent for water treatment (Mo *et al.,* 2018). Because of their porous structure and wide specific surface area with diverse functional groups, they absorb dye and heavy metal ions easily (Yadav *et al.,* 2021).

Adsorbents have been made from raw agricultural solid waste and waste materials from the forest industry. Because of their physicochemical properties and inexpensive cost, these materials are widely available and may have promise as sorbents (Boakye *et al.,* 2022). Aside from that, according to Boakye *et al.,* (2022), the characterization of adsorbents is done to clarify essential information regarding the structure and characteristics of the adsorbents, as well as maybe the interaction between the adsorbents and adsorbates. Fourier transforms infrared (FTIR) spectroscopy, scanning electron microscope (SEM), energy dispersive X-ray spectroscopy (EDX), Brunauer-Emmett-Teller analyzer (BET), Thermogravimetric Analyzer (TGA), CHNS, and elemental analysis (EA) are among the instruments used by researchers for characterizing the activated carbon (Boakye *et al.,* 2022).

As a consequence, plant-based agricultural waste adsorbents may be transformed by various physical processes such as grinding, cutting, drying, milling, boiling, thermal drying, and carbonization. These treatment methods often alter the adsorbent's pore size distribution, surface area, and moisture content, and the use of physically changed plant-based agricultural waste adsorbents for heavy metal ion and dye removal is reviewed (Yadav *et al.,* 2021).

Adsorbents generated from biomass have been effectively used in wastewater treatment to remove a variety of impurities (Solangi *et al.,* 2021). Due to their dual area contribution from activated carbon and nano-particles, nanoparticle-implanted activated carbons have greater adsorption kinetics and capacities for wastewater pollutants than traditional activated carbons (Solangi *et al.*, 2021). Furthermore, Solangi *et al.,* (2021) indicated that the number of active sites increases post-implantation, allowing for faster and larger pollutant adsorption as compared to traditional carbons. The implementation of biomass as an adsorbent might result in a large discharge of soluble organic compounds into the water body, which can cause undesirable increases in other parameters such as chemical oxygen demand (COD), biological oxygen demand (BOD), and total organic carbon (TOC) (Bashir *et al.,* 2019). As a result, creating ways for modifying biomass adsorbents is particularly desirable.

A broad range of technologies, involving solvent extraction, ion exchange, osmosis, membrane filtration, chemical precipitation, biosorption, and notably adsorption, has been tested to remove metals from polluted waterways (Punia *et al.,* 2022). Consequently, because of its simplicity, cost-effectiveness, non-toxicity, chemical, and mechanical stability, and local availability, the adsorption approach has become the ideal method for removing harmful heavy metals from wastewater (Buonomenna *et al.,* 2022). Furthermore, as compared to other approaches, the adsorption process is simpler and less expensive. Many parameters influence adsorption efficiency, including polarity, distribution, surface area, pore size, and adsorbent type (Tan *et al.,* 2021).

Adsorption is reversible, and adsorbents may be replenished using appropriate desorption procedures. Up to this point, several low-cost adsorbents for heavy metal ion (Calcium, magnesium and iron) removal have been developed and evaluated, with varied adsorption performances depending on the kind of adsorbents utilized (Chakraborty *et al.,* 2022). Adsorption is however a technique used to separate several applications, and the most crucial stage in employing the adsorption method is to develop good adsorbents that can not only trap heavy metal ions but also efficiently remove the dye (Borst *et al.,* 2020, Kuang *et al.*, 2020 and Pan *et al.*, 2019). Biochar has been widely employed in past research to improve water quality as a low-cost adsorbent from a variety of sources (Ding *et al.,* 2020 and Yuan *et al.,* 2021). Nevertheless, when compared to other types of adsorbents, biochar frequently displayed low adsorption capacity, a lack of affinity for heavy metal ions or organic pollutants, and most can only remove a single kind of heavy metal (Nguyen *et al.,* 2019 and Vieira *et al.,* 2019).

Other major sources of water contamination involve untreated sanitary and hazardous industrial waste discharge, dumping of industrial effluent, and runoff from agricultural areas, among others (Jayaswal *et al.,* 2018). To regulate water pollution, a range of treatment systems are available, with varying degrees of effectiveness. Even then, the majority of these systems have drawbacks such as high operational and maintenance costs, hazardous sludge formation, and difficult treatment procedures (Bhatnagar *et al.,* 2015). Also, adsorption is regarded as a preferable choice in water treatment due to its convenience, simple operation, and simplicity of design (Bhatnagar *et al.,* 2015). Furthermore, because this procedure can consider removing many types of contaminants, it has a broader use in water pollution prevention. Adsorbents are considered "low cost" if they need minimum processing, are plentiful, or are a by-product or waste material from the industry. It has recently been discovered that numerous low-cost adsorbents derived from diverse sources have little to no adsorption capacity for the removal of aquatic contaminants when contrasted to commercial activated carbon (Bhatnagar *et al.,* 2015).

Standard wastewater treatment is primarily concerned with controlling COD and BOD levels. In contrast, aside from typical biological treatment approaches, the problem of ammoniacal nitrogen removal has received little research. Due to the limits of both biological and standard physicochemical approaches, the ammoniacal nitrogen is a severe concern in many industrial wastewaters (Patil *et al.,* 2021). Adsorption is frequently used in this particular respect (Patil *et al.*, 2021). Adsorption is utilized because it is stable, easy to maintain, and trustworthy; thus, ammonia removal was found to be quite low (3-17%) (Patil *et al.*, 2021). As a result, the primary goal of this study is to examine the suitability of activated carbon as a filtering medium in combination with other approaches capable of reducing ammoniacal nitrogen. According to study's findings, around 40% of ammoniacal nitrogen with concentration of more than 1000 mg/L could be eliminated using activated carbon at a 5:35 mixing ratio (Aziz *et al.*, 2004).

Moreover, table attached below; Table 2.2 shows the proximate analysis and ultimate analysis of bamboo biomass. Furthermore, Table 2.2.1 shows the method for removing capacity. According to the table, chemical activation with potassium hydroxide can enhance the surface area, porous texture, and functional groups in FTIR, while also increasing the influence on removal capacity.

Table 2.2 Proximate Analysis and Ultimate Analysis of Bamboo Biomass.

	Proximate Analysis (%)				Ultimate Analysis (%)				
Bamboo Biomass	**Value Moisture**	**Ash**	**Fixed Carbon**	**Volatile Matter**	**C**	**H**	**O**	**N**	**References**
Moso Bamboo (Phyllostachys Edulis)		4.06 ± 0.06	80.19 ± 0.15	15.75 ± 0.22	89.63 ± 0.32	1.44 ± 0.02	8.46 ± 0.92	0.47 ± 0.03	Zhang *et al.*, 2017
Dendrocalamus Giganteus Munro	6.5 ± 1.0	3.9 ± 0.40	81.5 ± 0.40	8.10 ± 1.70	82.1 ± 0.6	2.72 ± 0.02	14.6 ± 0.6	0.54 ± 0.05	Hernandez-Mena *et al.*, 2014
Black Bamboo Charcoal		4.84	89.19	5.97	85.42	1.39	11.80	1.39	Pijarn *et al.*, 2021
White Bamboo Charcoal		2.26	95.14	2.60	90.67	0.44	8.45	0.44	Pijarn *et al.*, 2021
Bamboo	4.60	0.73	21.84	72.83	48.37	6.11	39.84	0.27	Yang *et al.*, 2022

Table 2.3 Method for Removing Capacity (Tan et al., 2017)

Feedstock	Pyrolytic Condition	Types of Methods	Technique Used	Characteristics	Contaminants	Effect on Removal Capacity	References
Corn Stalks	550 (-)	Physical activation	Activation with CO_2	Improved the pore structures	Methylene blue	Adsorption increased gradually with the increase of the activation time	Wang *et al.*, 2014
Giant Miscanthus	500 (1 h)	Physical activation	Steam activation	Higher surface area	Cu(II)	-	Shim *et al.*, 2015
Sicyos Angulatus L.	300, 700 (2 h)	Physical activation	Steam activation	Larger surface area and pore volume	Sulfamethazine	55% increase in sorption capacity	Rajapaksha *et al.*, 2015
Loblolly Pine Chip	300 (15 min)	Chemical activation	Chemical activation with NaOH	High surface area and microscope volume	Diclofenac, naproxen, and ibuprofen	-	Jung *et al.*, 2015
Municipal Solid Wastes	500 (0.5 h)	Chemical activation	Chemical activation with KOH	Increased of surface area, porous texture and functional groups	As(V)	More than 1.3 times of pristine biochar	Jin *et al.*, 2014

2.3 Ammoniacal Nitrogen Removal for Biochar

2.3.1 Effect of Water Eutrophication Pollution from Ammonia-nitrogen

Water eutrophication pollution caused by ammonia-nitrogen has become a severe environmental issue, prompting considerable concern among researchers. Biochar have been widely employed in the field of wastewater treatment in current years as a novel adsorbent due to their huge specific surface area, robust pore structure, easy method, and lack of activation or subsequent treatment. In addition, biochar is solid biomass that has been intended to form under oxygen-free conditions, such as wood, crop leftovers, or agricultural waste (Gupta *et al.,* 2022). Also, it has been utilized as a soil amendment, carbon sequestration agent, and adsorbent in aquatic settings to remove organic and inorganic chemicals. Furthermore, high ammonia-nitrogen concentrations drain much of the dissolved oxygen in water, worsening eutrophication, while nitrogen loss has been more and more extreme due to excessive nitrogenous fertilizer dose and low efficiency (Lencha *et al.,* 2021). Capturing and reusing ammonia-nitrogen is so crucial. Nevertheless, increasingly viable and appealing technologies regarding resource recovery, such as biochar absorption, are sustainable and may influence favourably the whole nitrogen balance as well as the efficiency of wastewater treatment (Türker *et al.,* 2017). Additionally, ammonium is one of the most common inorganic nitrogen forms in the aqueous phase, and the interconversion of ammonium and ammonia is pH and temperature-dependent (Zhang *et al.,* 2020). In most water environments with pH 8.2

and a temperature of 28°C, ammonium is the dominant form (>90%) over ammonia (Zhang *et al.*, 2020).

Following that, according to the 2010 Bulletin of the First Survey for Chinese Pollution Sources, the cumulative ammonium nitrogen emission was 1.72 million tons (Zhang *et al.*, 2013). As a result, ammonium nitrogen treatment is a focus for environmental pollution management. Management of ammonium nitrogen is difficult and often necessitates the use of many methods. Many techniques, including biological nitrification, stripping, precipitation, and adsorption, can be used in the treatment of ammonium nitrogen (Xiang *et al.*, 2020). Further, Zhang *et al.*, (2013) indicate that the produced biochar was characterized using a Transmission Electron Microscope with energy-dispersive X-ray spectroscopy, X-ray diffraction, and Fourier Transform Infrared spectroscopy. The ideal solution pH and the influence of coexisting ions on ammonium nitrogen removal from wastewater were investigated. Aside from that, surface characterization revealed that the resulting biochar was coarse, unshaped, irregular, and high in carbon. Biochar adsorption of ammonium nitrogen decreased as solution pH increased, and when coexisting ion concentration increased, biochar adsorption of ammonium nitrogen decreased (Zhang *et al.*, 2013). Along with that, Tan et el., (2017) revealed table on the adsorption characteristics of various contaminants with activated biochar. Furthermore, the table below shows the adsorption characteristics of various contaminants with activated biochar.

Table 2.4 Adsorption characteristics of various contaminants with activated biochar (Tan *et al.*, 2017)

Feedstock Activated Carbon	Pyrolytic Condition	Activating Agent	BET Surface Area (m^2g^{-1})	Adsorption Temperature (ºC)	Adsorption pH	Adsorption Dosage (gL^{-1})	Contaminants	Q_{max} (mg/g)	Isotherm	Kinetic Model	References
Bamboo	550 (-)	$KMnO_4$	27.2 N_2	-	-	75	Furfural	93.55 (L)	L	PSO	Li *et al.*, 2014
Bamboo	550 (-)	HNO_3	0.5 N_2	-	-	75	Furfural	96.34 (L)	L	PSO	Li *et al.*, 2014
Bamboo	550 (-)	NaOH	0.4 N_2	-	-	75	Furfural	102.04 (L)	L	PSO	Li *et al.*, 2014
Bamboo waste	450 (1 h)	Steam	1210 N_2	25	-	4	Methylene blue	330 (L)	L	PSO	Zhang *et al.*, 2014

CHAPTER 3

METHODOLOGY

3.1 Sample Collection

Bamboo *Dendrocalamus asper* biochar was collected from Asper Supplies Sdn. Bhd.

3.2 Preparation of Bamboo Biochar

3.2.1 Sample Preparation Treatment (Ant Supplies Sdn. Bhd.)

The original form of bamboo biochar was cut into smaller pieces approximately 3 cm x 8 cm – 8.5 cm. The bamboo biochar from Ant Supplies Sdn. Bhd. then crushed until it became powder (Czajczyńska *et al.*, 2017). The biochar was placed in a 1000 mL beaker. The impregnation ratio of the treatment was 5:1 ratio. The ratio of concentrated potassium hydroxide was 5 and the ratio of biochar was 1. Then, 100 mL of deionized water was added to the 5:1 ratio of concentrated potassium hydroxide and deionized water before being poured into the biochar-containing beaker. After that, leave it overnight in the oven (24 hours), the biochar will then absorb the acid to begin the activation process using the furnace at 500ºC for 2 hours.

3.2.2 Characterization of Fourier-transform Infrared Spectroscopy (FTIR)

To prepare for FTIR analysis, each sample was crushed and 1 mg of biochar was used. FTIR analyses on both treated and untreated samples were done to identify the surface functional group of biochar using the FTIR instrument (L1600107 PerkinElmer).

3.3 Preparation of Ammoniacal Nitrogen

3.3.1 Standard Solution of Ammoniacal Nitrogen Preparation

Diluted 3.819 g of anhydrous ammonium nitrate in 1000 mL of ammonia-free water (Choudhary, n.d.). The ammonia then removed by boiling 50g Rochelle salt solution with 100 mL deionized water. The ammonium standard was made using stock solutions of 10, 20, 30, 40, and 50 mg/L using 10, 20, 30, 40, and 50 mL of ammonium nitrate solution, respectively (Fakhre and Ibrahim, 2018). After a five-minute break, 1 mL of Rochelle salt solution and 1 mL of Nessler's reagent were added. The diluted solutions of the ammoniacal nitrogen concentrations were suitably prepared for the next batch of adsorption procedures. The ammoniacal nitrogen concentration was evaluated using a UV-Vis Spectrophotometer (LAMBDA 365+ PerkinElmer).

3.4 Preparation of Batch Experiment

In various conical flasks, 0.04 g of biochar was mixed with 50 mL of fixed-concentration ammoniacal nitrogen solutions. The mixtures were agitated at 150 rpm for 300 minutes (Shi *et al.*, 2016) at 298 K room temperature. Using equation given, the quantity of ammoniacal nitrogen adsorbed, Qe (mg/g), was estimated:

Adsorption Capacity: $Q_e = \frac{(C_i - C_e)V}{m}$ (1)

Where:

Q_e is equilibrium capacity (mg/g)

V = Volume of ammoniacal nitrogen solution (mL)

m = Mass of activated carbon (g)

C_i = Initial concentration of ammoniacal nitrogen (mg/L)

C_f = Final (equilibrium) concentration of ammoniacal nitrogen (mg/L) (1)

The percentage of removal calculated by:

% Of removal $= \frac{\text{Initial}-\text{Final}}{\text{Initial}} \text{ x } 100$ (2)

Where:

% removal = Percentage of removal

Initial = The initial measurement before treatment of wastewater

Final = The final measurement after treatment of wastewater (2)

3.5 Parameter Experiment

3.5.1 The Effect of Mass Sample Dosage

By mixing 50 mL of constant concentrations of ammoniacal nitrogen solutions with 0.005, 0.01, and 0.05 g of biochar, held for 300 minutes at a stirring rate of 150 rpm (Shi *et al.,* 2016) at 298 K, the effects of the adsorbent dose were analysed.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Ammoniacal Nitrogen Adsorption Batch Test

In the standard curve of ammonium nitrate solution vs. absorbance, the formula for a linear equation was $y=0.703x + 0.0887$, and the value of r^2 was 0.9845, which is close to 1. These were used to calculate the concentration of an ammonium nitrate solution that had been mixed with biochar samples.

Figure 4.1 reveals that shortly after 143 minutes, the graph had a smaller amount of gradient, indicating that the adsorption capacity of ammoniacal nitrogen increased with increasing contact time up to the point they reached near-surface saturation. This adsorption of ammoniacal nitrogen onto biochar samples indicates that this is the best contact hour for moving on to the next step of the parameter: mass dosage. Furthermore, it was revealed that the ammoniacal nitrogen concentrations showed distinctive adsorption concentrations regardless of time.

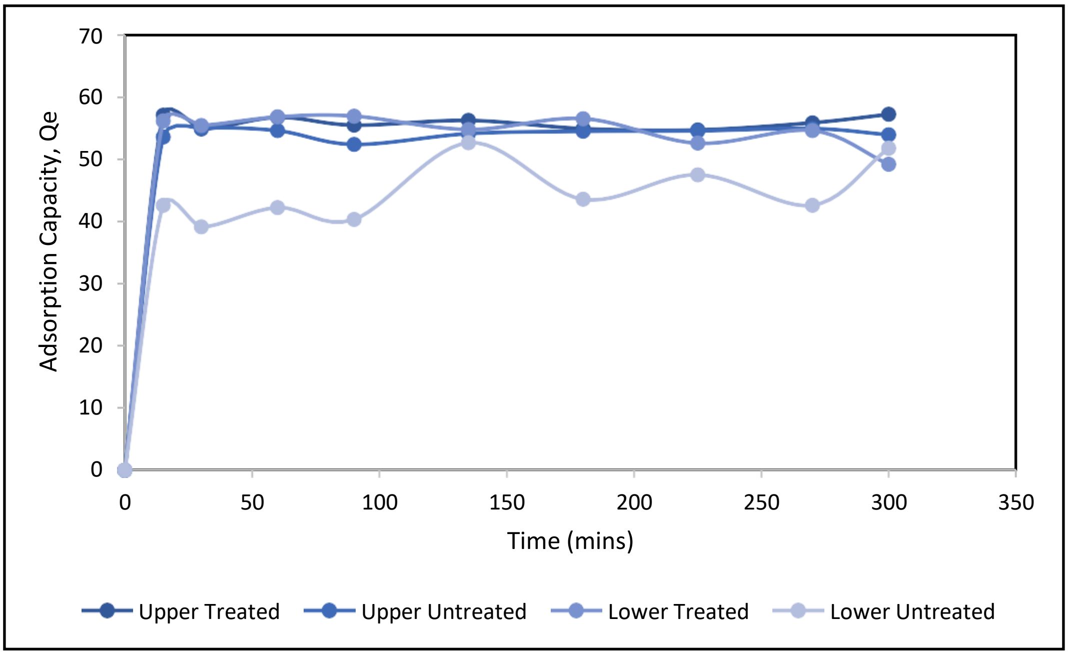

Figure 4.1 The effect of shaking/contact time on versus ammoniacal nitrogen removal by biochar samples (Weight of bio sorbent: 0.04 g, Volume: 50 mL, Agitated Speed: 150 rpm, Contact Time: 300 minutes)

4.2 The Effect of Mass Dosage

Table 4.1 and Table 4.2 shows the influence of the dosage of adsorbent on ammoniacal nitrogen adsorption by biochar samples; treated and untreated. According to the tables below, the bigger the amount of mass dosage used, the higher the percentage of removal results. The percentage removal rose from 0.005 g to 0.01 g to 0.05 g in 50 mL of constant concentration ammoniacal nitrogen ammonia solutions. This is because increasing the adsorbent amount increased the adsorbent's surface area and the number of possible adsorptive sites. As adsorbent mass rose, more surface area became accessible, increasing the overall number of binding sites (Dovi *et al.*, 2022). Inversely, adsorption capacity reduced as the dose rose from 0.005 g to 0.01 g and 0.05 g.

Table 4.1 Effect of adsorbent dosage on percentage removal and amount of ammoniacal nitrogen adsorbed at equilibrium on ammoniacal nitrogen by biochar samples (treated).

Dosage (g) (Treated)	**Removal (%)**	**Adsorption Capacity, Q_e (mg/g)**
0.005	91.76	458.82
0.01	92.15	230.27
0.05	92.19	46.08

Table 4.2 Effect of adsorbent dosage on percentage removal and amount of ammoniacal nitrogen adsorbed at equilibrium on ammoniacal nitrogen by biochar samples (untreated).

Dosage (g) (Untreated)	**Removal (%)**	**Adsorption Capacity, Q_e (mg/g)**
0.005	88.96	443.58
0.01	89.30	221.65
0.05	89.34	44.11

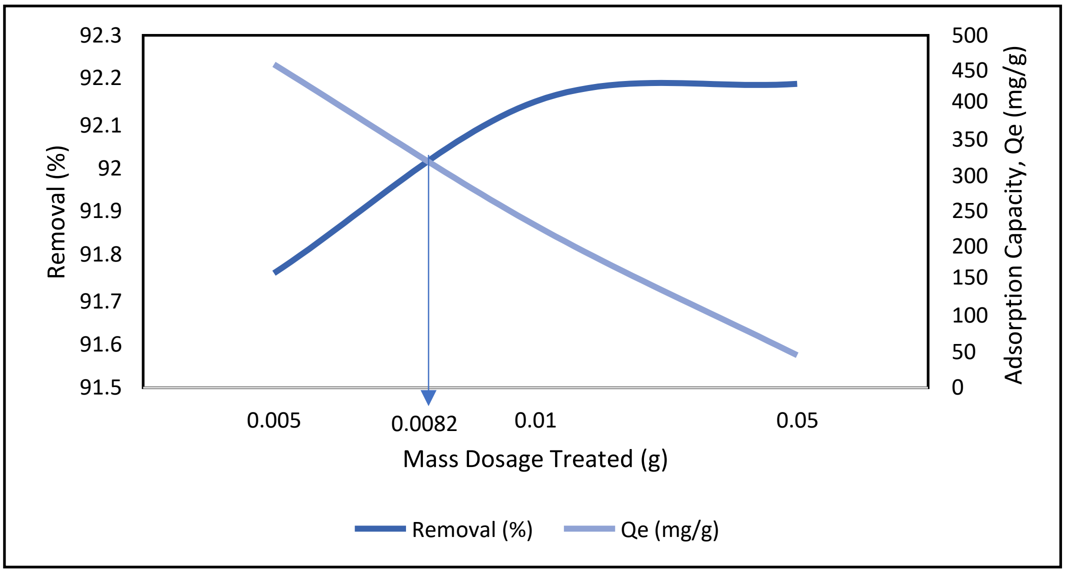

Figure 4.2 Adsorbent dosage effect on ammoniacal nitrogen adsorption by biochar samples; treated (Weight of bio sorbent: 0.005 – 0.05 g, Volume: 50 mL, Agitated speed: 150 rpm, Contact time: 143 minutes)

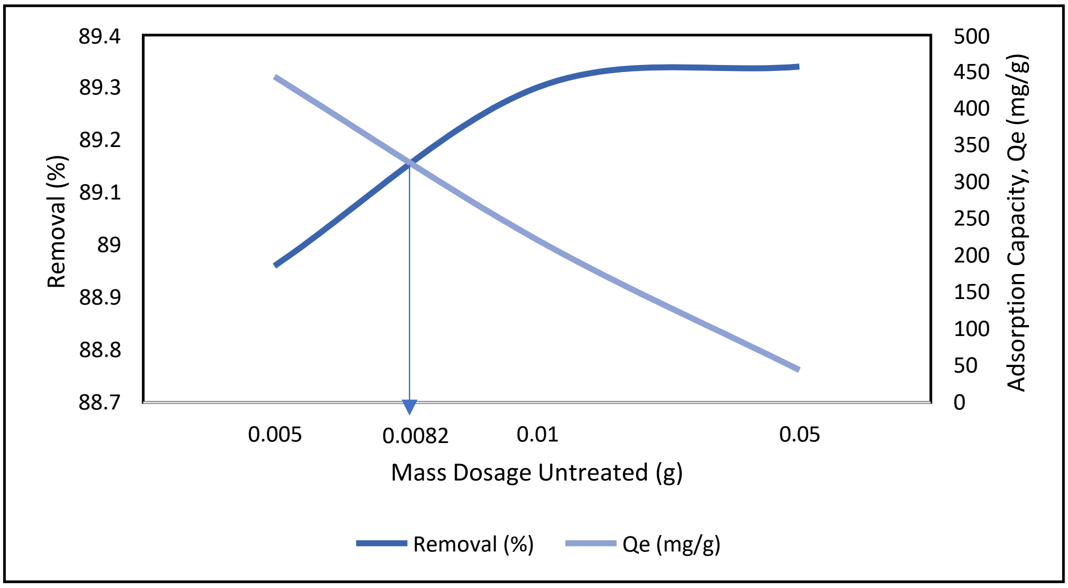

Figure 4.3 Adsorbent dosage effect on ammoniacal nitrogen adsorption by biochar samples; untreated (Weight of bio sorbent: 0.005 – 0.05 g, Volume: 50 mL, Agitated speed: 150 rpm, Contact time: 143 minutes)

Adsorption capacity from my study was a bit different which is only 0.2 g for treated and 1.77 g for untreated at 0.05 g mass dosage compared to Table 2.1 under unmodified biochar. According to Figure 4.2 and Figure 4.3, the percentage removal of ammoniacal nitrogen against mass dosage appears on the first axis of the chart, whereas the adsorption capacity of ammoniacal nitrogen against dosage belongs on the second axis. Following what has been shown in Figure 4.2, when the treated biochar dosage rose, the adsorption capacity fell gradually, while the removal efficiency improved over time and remained stable after the treated biochar dosage reached 0.0082 g. The equilibrium adsorption capacity decreased as the treated biochar dose increased, resulting was connected to adsorption site aggregation as well as a reduction of the absorbed area. As soon as the treated biochar dosage was low, the distance within particles was large, allowing even more ammonium ion aggregation surrounding each particle enabling effective ion exchange between the treated biochar and ammonium ion; as a consequence, increasing the treated biochar dosage allowed more adsorption sites, potentially increasing removal efficiency and the number of ion exchange sites (Barquilha & Braga, 2021). The exceptionally high adsorbent concentration provided a protective effect on the perimeter, preventing the adsorbate and adsorption site from combining and thereby lowering adsorption capacity. As a result, the treated biochar dosage of 0.0082 g was determined for the following experiment.

Next, Figure 4.3 shows the trend for untreated biochar is the same as for treated biochar, however, for untreated biochar, the adsorption capacity fell gradually, while the removal efficiency improved over time and remained stable after the treated biochar dosage reached 0.0082 g too. The equilibrium adsorption capacity decreased as the treated biochar dose increased, resulting was connected to adsorption site aggregation as well as a reduction of the absorbed area (Kaya & Uzun, 2021). As soon as the treated biochar dosage was low, the distance within particles was large, allowing even more ammonium ion aggregation surrounding each particle enabling effective ion exchange between the treated biochar and ammonium ion; as a consequence, increasing the treated biochar dosage allowed more adsorption sites, potentially increasing removal efficiency and the number of ion exchange sites (Akhil *et al.,* 2021). The exceptionally high adsorbent concentration provided a protective effect on the perimeter, preventing the adsorbate and adsorption site from combining and thereby lowering adsorption capacity (Surana *et al.,* 2022). As a result, the untreated biochar dosage of 0.0082 g was determined for the following experiment. Besides, Ma *et al.*, (2021) employed the same mass dosage as my research, and the optimal dose was found to be 0.01 g after 120 minutes. This differs somewhat from my results since my discussion's duration was 143 minutes, which is a little longer than the research.

4.3 FTIR Analysis of the Functional Groups of Biochar Samples Before and After

Figure 4.5 and Figure 4.6 depicts the FTIR spectrum of biochar-ammoniacal nitrogen before and after adsorption at upper and lower biochar samples. indicates weak broad adsorption peaks at 1370.12 cm^{-1} and 1558.67 cm^{-1} for upper treatment. It demonstrates the stretching of O-H alcohols as well as the aromatic rings. The existence of a strong peak at 958.27 cm^{-1} may be attributed to the presence of C=C alkene (Ma *et al.*, 2021). At 705.20 cm^{-1}, there is a weak broad, intense adsorption peak. It demonstrates the bending of the alkene group. Because of the existence of C-H bent adsorption, the medium bend within the range of region 1444.55 cm^{-1} aromatic ring for lower treatment. The peak at 1355.23 cm^{-1} can be attributed to the presence of O-H bending caused by the alcohol group. The strong peak at 963.23 cm^{-1} indicates the possibility of C=C owing to an alkene. The appearance of a peak at 700.24 cm^{-1} may be attributable to C-H bending caused by monosubstituted.

Figure 4.6 and Figure 4.7 demonstrated several variations in peaks when contrasted to the spectra of untreated biochar. We can notice that the upper untreated has a greater intensity than the upper treated at a peak of 1745.77 cm^{-1} due to the considerable stretching of C-H (Alam *et al.,* 2018). The extending of the band peak in the spectrum indicates that the peak at 1367.54 cm^{-1} has a larger intensity than the upper treated. The peak at 1039.74 cm^{-1} demonstrates that the upper treated has lesser intensity than the upper untreated as a result of the existence of C-H bending, but both exhibit strong stretching. Some peaks are present at 787.59 cm^{-1}. This might indicate an appearance of C-H bending, as the strength of that C-H in-plane bending vibration has increased from 705.20 cm^{-1} in the upper treated spectrum. Lower untreated is forthcoming. The existence of C-H bonding owing to aromatic is revealed by 1871.84 cm^{-1} from lower untreated, and the intensity is somewhat greater than lower treated. It demonstrated the presence of C-H broadband peak in lower untreated at peak 1463.36 cm^{-1}, indicating that it contains several shoulders and small bands that contribute to a higher intensity than lower treated. The peak at 1029.66 cm^{-1} might be attributed to the existence of C-OH bonding, which had substantially stronger stretching than the lower treatment, which had 963.23 cm^{-1}. Finally, the peak at 700.24 cm^{-1} in the lower treated spectrum has moved up to 873.32 cm^{-1} in the lower untreated spectrum, indicating a rise in the strength of C-H bonding in-plane vibration.

As a result, the FTIR spectra show that ammoniacal nitrogen adsorption on biochar samples happened through hydrogen bonding, ion exchange, and electrostatic interactions. Figure 4.4 shows the structure of functional groups commonly found on biochar surfaces and bamboo biochar main compositions from my study and Figure 4.5 shows the chemical structure of lignin.

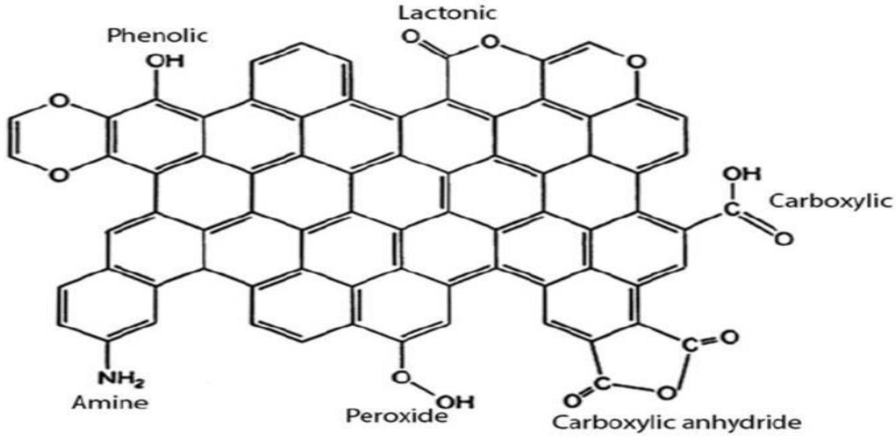

Figure 4.4 Functional groups commonly found on biochar surfaces (Hue, 2020)

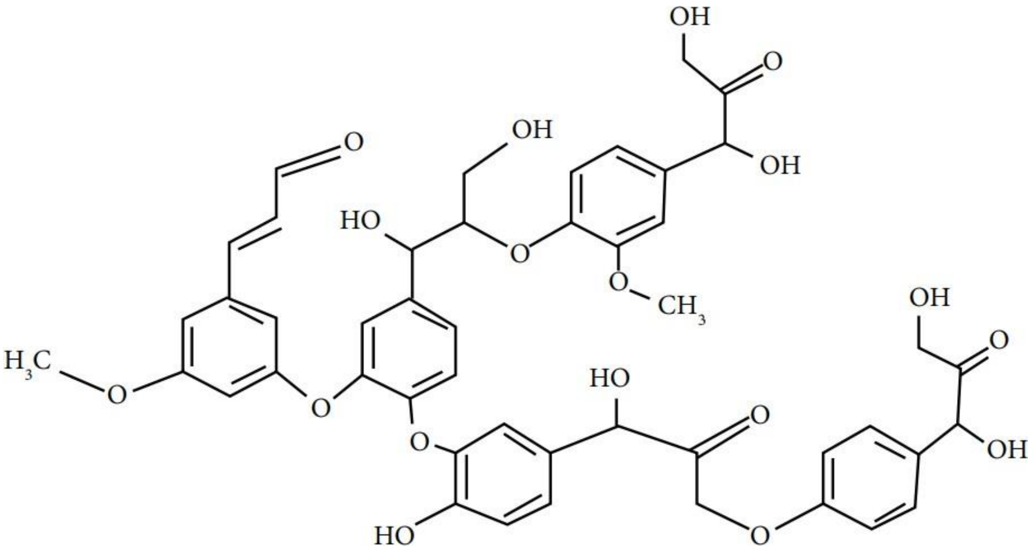

Figure 4.5 Chemical structure of lignin (Riki *et al.*, 2019)

According to Zao *et al.,* (2023), coal fly ash was employed in the study. Their results varied somewhat from mine, but the majority of them fall into the same functional groupings. CFA experienced changes, leading to enhanced hydrogen bonding and bending vibrations, according to Zao *et al.,* (2023). The addition of NaOH strengthened intermolecular hydrogen bonds, whereas stretching vibrations from SiO_4 or AlO_4 created a strong peak at 1080 cm^{-1}. The internal structure of

NaOH-CFA altered, and O-Si-O stretching vibrations emerged at 820 cm^{-1}. Bending vibrations of Si-O-Si were found at 460 cm^{-1}.

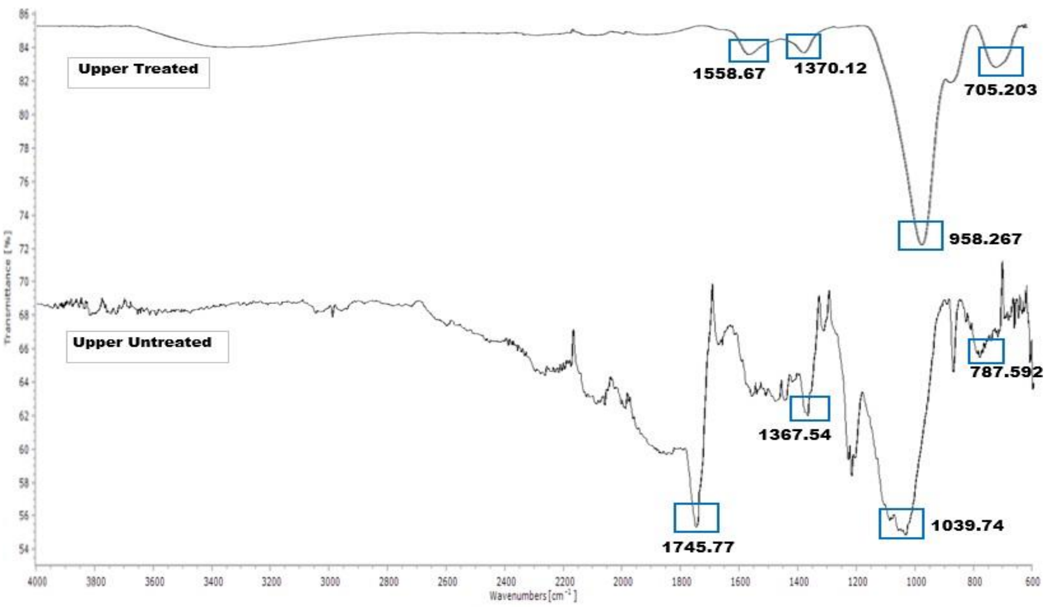

Figure 4.6 FTIR Analysis of the Functional Groups of Biochar Samples Before and After Treatment (Upper)

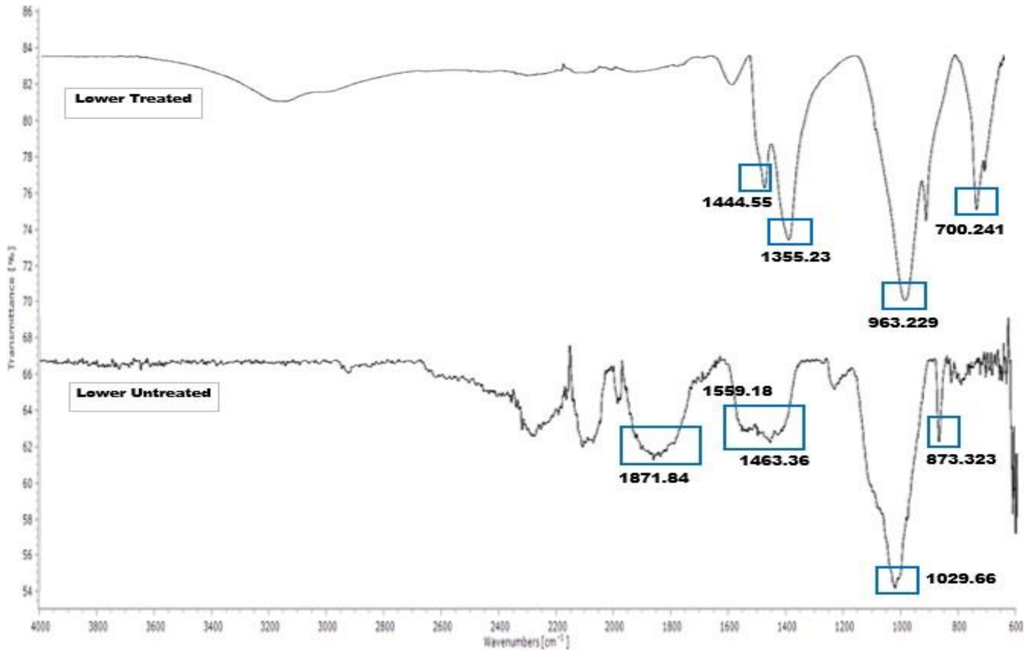

Figure 4.7 FTIR Analysis of the Functional Groups of Biochar Samples Before and After Treatment (Lower)

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

In a nutshell, the results suggest that the adsorption capacity of ammoniacal nitrogen from the batch experiment is 54 g/mg based on the ammoniacal nitrogen adsorption of the upper-treated bamboo biochar. The best contact time for the batch experiment in this study is 143 minutes after 300 minutes of agitation. As a result of this research, bamboo biochar has been identified as a viable absorbent for the removal of ammoniacal nitrogen from wastewater treatment. Mass dosages of 0.005 g, 0.01 g, and 0.05 g were revised. The adsorption capacity of treated biochar decreased as the dosage increased, resulting in adsorption site aggregation and reduced absorbed area. Low treated biochar dosage led to larger particle distances, allowing more ammonium ion aggregation and effective ion exchange. Increased biochar dosage allowed more adsorption sites, potentially increasing removal efficiency and ion exchange sites. The high adsorbent concentration protected the perimeter, lowering adsorption capacity.

The treated biochar dosage of 0.023 g was determined for the experiment. Meanwhile, untreated biochar experienced a gradual decrease in adsorption capacity, while removal efficiency improved over time. The untreated biochar dosage reached 0.023 g too, causing adsorption site aggregation and reduced absorbed area. As the treated biochar dosage increased, particles became larger, allowing more ammonium ion aggregation and effective ion exchange. Increased biochar dosage allowed more adsorption sites, potentially increasing removal efficiency and ion exchange sites. The high adsorbent concentration protected the perimeter, lowering adsorption capacity. The treated biochar dosage was determined for the experiment. Furthermore, it was discovered regarding the FTIR spectrum characterization of bamboo biochar before and after treatment that the surface of functional group after chemical treatment. The FTIR spectrum of biochar-ammoniacal nitrogen for upper treatment, indicating stretching of O-H alcohols and aromatic rings, the presence of C=C alkene, the bending of the alkene group, and aromatic ring for lower treatment is due to C-H bent adsorption.

According to the findings of this study, biochar is an effective adsorbent for wastewater treatment. Biochar can assist to decrease contaminated effluent and enhance water quality when treated with it. Given the ease with which bamboo can be obtained, it might be beneficial to do further study and research on wastewater treatment. To enhance these findings from experiments, the isotherm and using real wastewater should be done. Aside from that, bamboo biochar can be physically treated with carbon dioxide or stream to improve the adsorption sites surface of the bamboo biochar, which may enhance the adsorption capacity of the bamboo biochar of ammoniacal nitrogen. Other than that, BET analysis and the Langmuir/Freundlich isotherm and real adsorption with agricultural wastewater should be considered for future research.

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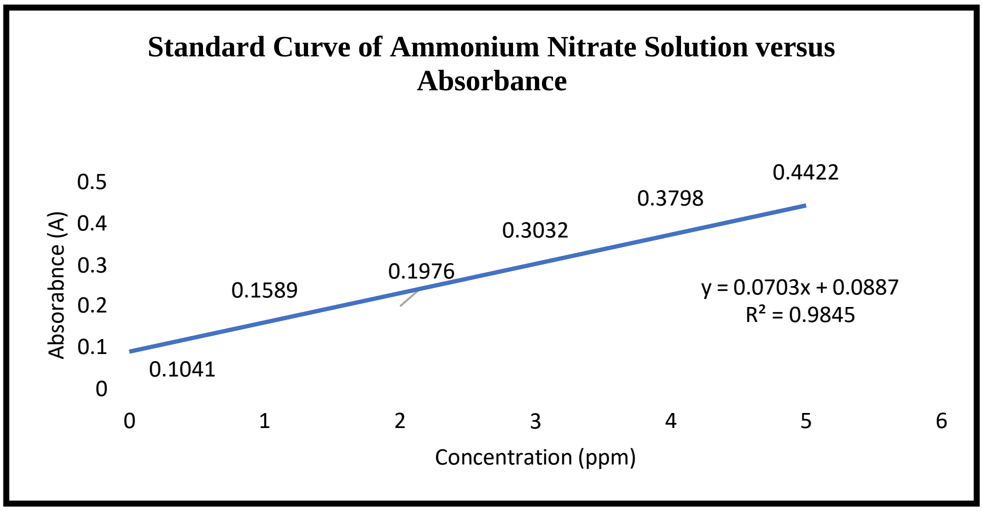
APPENDICES

Upper and lower bamboo biochar from Asper Supplies Sdn. Bhd.

Crush bamboo biochar until become powder

Preparation of standard ammoniacal nitrogen standard solution



Standard calibration curve of ammonium nitrate solution versus absorbance

CURRICULUM VITAE

A. Personal profile

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B. Hobbies and Interests

I adore exploring the kitchen. Love learning new culinary or baking methods, particularly in Western cuisine. I also potted for my mother's plant.

C. Academic qualifications

Degree	Area	Institution	Year Awarded
B.Sc. (Hons.)	Chemistry with Management	Universiti Teknologi MARA, Malaysia	2023
Diploma	Industrial Chemistry	Universiti Teknologi MARA, Malaysia	2020
S.P.M	Science	Sekolah Menengah Sains Kuching	2016

D. Work experience

Post	Place	Year
Intern	Sarawak Energy Berhad	2020

E. Related experience

Post	Place	Year
EXCO Protocol	CHEMISTS Faculty of Applied Sciences, UiTM	2021-2022
Vice President	PRISMATICS (Degree), UiTM	2021-2022
Vice Treasurer	PRISMATICS (Degree), UiTM	2020-2021
Facilitator	KKI (Kem Kepimpinan Islam), UiTM	2019

F. Awards

Type	Name of award / awarding organization	Year
Certificate	Dean’s List Award 2023, Universiti Teknologi MARA	09 March 2023

Certificate	Dean’s List Award 2021, Universiti Teknologi MARA	11 March 2021

G. Other Relevant Information