



UNIVERSITI PUTRA MALAYSIA

***ADSORBENT DERIVED FROM SUGARCANE BAGASSE AND CORN
HUSK FOR POTENTIAL AMMONIA GAS REMOVAL***

BILLY GUAN TECK HUAT

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BILLY GUAN TECK HUAT

MASTER OF SCIENCE

UNIVERSITI PUTRA MALAYSIA

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UPM
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BERILMU BERBAKTI

**ADSORBENT DERIVED FROM SUGARCANE BAGASSE AND CORN
HUSK FOR POTENTIAL AMMONIA GAS REMOVAL**

By

BILLY GUAN TECK HUAT

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfillment of the Requirements for the Degree of Master of Science**

September 2013

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

ADSORBENT DERIVED FROM SUGARCANE BAGASSE AND CORN HUSK FOR POTENTIAL AMMONIA GAS REMOVAL

By

BILLY GUAN TECK HUAT

September 2013

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Faculty : Environmental Studies

Agriculture wastes such as sugarcane bagasse (SB) and corn husk (CH) can be converted into low-cost adsorbents. The conversion of SB and CH into adsorbent will have two purposes. First, unwanted agricultural wastes are cheap, renewable, and abundant and thus can be converted into useful, added value adsorbents and second, the use of agricultural wastes as raw materials for making adsorbents can contribute in solving parts of the solid waste management and treatment problems in the country. The raw fibers were made into pellets of known composition (mixing ratios) of SB and CH. They were then converted into activated carbon through a physical activation method in which they undergo carbonization heat treatment at 800 °C under nitrogen atmosphere, followed by activation in air for 40 minutes. For the first objective in this study, both the raw fiber and the activated carbon of SB and CH (SBCHAC) pellets were characterized for their physical and chemical properties in which they are performed by proximate analysis, ultimate analysis, surface pH, thermogravimetric analysis, porosity analysis, Fourier transform infrared spectroscopy, scanning electron microscopy, and energy dispersive X-ray. For the second objective, the adsorbents were assessed to determine their ability and potential to remove gaseous ammonia (NH₃) due to ubiquity in the environment and risk to human health. The study found that the activated carbon labeled SBCHAC4 with a Brunauer-Emmett-Teller surface area of 255.909 m² g⁻¹ had the highest removal efficiency for NH₃, which is in overall slightly less superior to the commercial coconut kernel activated carbon. The results also show a statistically significant difference in the removal efficiency of NH₃ by SBCHAC4 between different NH₃ concentrations. The NH₃ adsorption by SBCHAC4 was found to follow the Langmuir and Freundlich isotherm model, and the adsorptive capacity of NH₃ for SBCHAC4 was 0.495 mg g⁻¹. Finally for the third objective, the production yield of SBCHAC4 was determined and the production cost of SBCHAC4 was estimated to assess its affordability due to the fact that commercially available activated carbons are still expensive because of the use of non-renewable and

relatively high-cost starting material. The activated carbon preparation for SBCHAC4 has resulted in 29.73% of yield. The studies indicate that SBCHAC4 could be listed as one of the most economical and effective adsorbent to be produced, which is justified in pollution control applications.



Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan ijazah Master Sains

**PENYERAP DARIPADA HAMPAS TEBU DAN SEKAM JAGUNG UNTUK
PENYINGKIRAN GAS AMMONIA**

Oleh

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Pengerusi : Profesor Madya Puziah Abdul Latif, PhD

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Sisa-sisa pertanian seperti hampas tebu (SB) dan sekam jagung (CH) boleh ditukarkan kepada penjerap yang berkos rendah. Penukaran SB dan CH kepada penjerap adalah disebabkan dua tujuan utama. Pertama, sisa-sisa pertanian yang tidak digunakan lagi adalah murah, boleh diperbaharui dan didapati wujud dalam kuantiti yang banyak dan dengan itu ia adalah sesuai ditukarkan kepada penjerap yang berguna dan bernilai tambah. Kedua, penggunaan sisa-sisa pertanian sebagai bahan mentah untuk membuat penyerap boleh membantu menyelesaikan sebahagian masalah daripada pengurusan dan rawatan sisa pepejal yang dihadapi oleh negara ini. Gentian mentah daripada SB dan CH dijadikan pelet dengan komposisi (nisbah-nisbah campuran) yang berlainan. Kemudian, pelet-pelet tersebut dirawat dengan pengaktifan fizikal di mana ia dikarbonisasi oleh rawatan haba pada suhu 800 °C dalam atmosfera nitrogen, dan diikuti oleh pengaktifan dalam udara selama 40 min. Untuk objektif pertama dalam kajian ini, kedua-dua jenis pelet iaitu gentian mentah dan karbon teraktif dikaji ciri-ciri fizikal dan kimianya di mana ia dilakukan oleh “proximate” analisis, “ultimate” analisis, pH permukaan, thermogravimetrik analisis, porositi analisis, spektroskopi inframerah transformasi Fourier, mikroskop elektron pengimbas, dan serakan tenaga sinar-X. Untuk objektif kedua, penjerap dinilai dengan menentukan keupayaan and potensinya dalam penyingkiran gas ammonia disebabkan kemelataan ammonia di persekitaran dan risikonya kepada kesihatan. Hasil kajian mendapati bahawa karbon teraktif berlabel SBCHAC4 dengan luas permukaan Brunauer-Emmett-Teller sebanyak 255.909 m² g⁻¹ mempunyai kecekapan penyingkiran tertinggi bagi ammonia, namun, secara keseluruhan, kecekapan penyingkirannya adalah sedikit kurang daripada karbon teraktif kopra komersil. Hasil kajian juga menunjukkan perbezaan statistik yang signifikan dalam kecekapan penyingkiran ammonia oleh SBCHAC4 pada kepekatan ammonia yang berbeza. Penjerapan ammonia oleh SBCHAC4 didapati mengikut model isoterm adsorpsi Langmuir and Freundlich, dan didapati juga keupayaan serapan ammonia bagi SBCHAC4 adalah 0.495 mg g⁻¹. Akhir sekali, untuk objektif ketiga, hasil

pengeluaran SBCHAC4 ditentukan dan kos pengeluaran SBCHAC4 dianggarkan untuk menilai kemampuan pembeliannya disebabkan kepada fakta bahawa terdapat karbon teraktif komersil yang masih mahal kerana penggunaan bahan mentah yang tidak boleh diperbaharui dan agak tinggi kosnya. Hasil sebanyak 29.73% dapat dikeluarkan dalam proses penyediaan karbon teraktif bagi SBCHAC4. Kajian ini dapat menunjukkan bahawa SBCHAC4 boleh disenaraikan sebagai salah satu penjerap yang paling ekonomi dan berkesan yang dapat dihasilkan bagi aplikasi kawalan pencemaran udara.



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I certify that a Thesis Examination Committee has met on 30 September 2013 to conduct the final examination of Billy Guan Teck Huat on his thesis entitled “Assessment of Adsorbent Derived from Sugarcane Bagasse and Corn Husk for Potential Ammonia Gas Removal” in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

BILLY GUAN TECK HUAT

Date: 30 September 2013

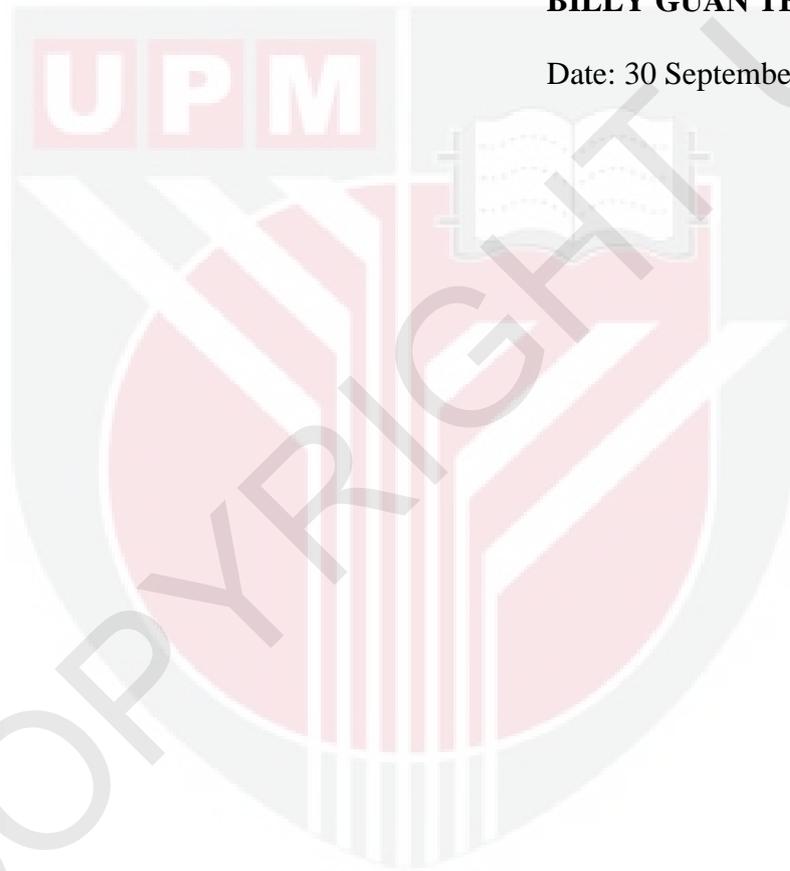


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LIST OF SYMBOL

%	Percentage of weight
lb ft ⁻³	Pounds per cubic foot
°C	Celsius
nm	Nanometers
ppm	Parts per million
min	Minutes
m	Meters
cm	Centimeters
ha	Hectares
mm	Millimeters
L	Liters
L min ⁻¹	Liters per minute
mL min ⁻¹	Milliliters per minute
h	Hours
g	Grams
mg	Milligrams
mL	Milliliters
µm	Micrometers
K	Kelvin
kPa	Kilopascal
ppb	Parts per billion
mg g ⁻¹	Milligrams per gram
mg L ⁻¹	Milligrams per liter
L mg ⁻¹	Liters per milligram

g cm^{-3}	Grams per cubic centimeter
cm^3	Cubic centimeters
$\text{cm}^3 \text{g}^{-1}$	Cubic centimeters per gram
$\text{m}^2 \text{g}^{-1}$	Square meters per gram
Å	Angstroms (1×10^{-10})
RM	Ringgit Malaysia



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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
ASTM	American Standard Test Method
AW	Agricultural Waste
BERNAMA	Malaysian National News Agency
BET	Brunauer-Emmett-Teller
CF	Correction factor
CH	Corn husk
CHNS	C (carbon), H (hydrogen), N (nitrogen), and S (sulfur) analysis
ComCKAC	Commercial coconut kernel activated carbon
CR	Crop residue
DOE	Department of Environment
DOSH	Department of Occupational Safety and Health
EDX	Energy dispersive X-ray
FAO	Food and Agriculture Organization of the United Nations
FT-IR	Fourier transform infra-red spectrophotometer
IDLH	Immediate dangerous to life or health
NIOSH	National Institute of Occupational Safety & Health
OSHA	Occupational Safety and Health Act
PEL	Permissible exposure limits
PTFE	Polytetrafluoroethylene
RE	Removal efficiency (%)
REL	Recommended exposure limit
RFP1	Raw fiber pellet with type 1 mixing ratio (0% SB : 100% CH)
RFP2	Raw fiber pellet with type 2 mixing ratio (30% SB : 70% CH)

RFP3	Raw fiber pellet with type 3 mixing ratio (50% SB : 50% CH)
RFP4	Raw fiber pellet with type 4 mixing ratio (90% SB : 10% CH)
RFP	Raw fiber pellets
RMAQG	Malaysian Air Quality Guidelines
SB	Sugarcane bagasse
SBCHAC1	Sugarcane bagasse corn husk activated carbon with type 1 mixing ratio (0% SB : 100% CH)
SBCHAC2	Sugarcane bagasse corn husk activated carbon with type 2 mixing ratio (30% SB : 70% CH)
SBCHAC3	Sugarcane bagasse corn husk activated carbon with type 3 mixing ratio (50% SB : 50% CH)
SBCHAC4	Sugarcane bagasse corn husk activated carbon with type 4 mixing ratio (90% SB : 10% CH)
SBCHAC	Sugarcane bagasse corn husk activated carbons
SEM	Scanning electron microscope
STEL	Short-term exposure limit
TGA	Thermogravimetric analysis
TWA	Time-weighted average
U.S. EPA	United States Environment Protection Agency
U.S. OSHA	United States Occupational Safety and Health Administration
USECHH	Occupational Safety and health (Use and Standards of Exposure of Chemicals Hazardous to Health) Regulations 2000
VOCs	Volatile organic compounds

CHAPTER 1

INTRODUCTION

1.1 General introduction

Filtration is a typical process where a substance is separated from another by entrapping it within the matrix structure of the filter medium via the process of adsorption or absorption; while adsorption is the process through which a substance, originally present in one phase is removed from that phase by accumulation at the interface between that phase and a separate (solid) phase. The filter media could be made out of natural or synthetic material. Nowadays, there are many types of filter media existing in the market such as sand, diatomaceous earth, granular or multi-media, activated carbon, membrane, and fabric (Purchas and Sutherland, 2002). In this study, selected agricultural waste (AW) was used in constructing the adsorption medium or adsorbent. Two types of commercial plants were selected particularly for this study and they were sugarcane and corn. Sugarcane is usually planted for their sweet nectar juice. Countries like Mexico uses sugarcane juice to produce ethanol in bio-diesel. A corn or *Zea mays* is an edible vegetable and is popular worldwide. Corn is believed to have originated in North America regions. Corn is harvested for their kernels or fruits and then they will undergo additional processes to produce a variety of products for global market. After harvesting, the remaining by-products of sugarcane and corn like for instance sugarcane bagasse (SB) and corn husk (CH) will eventually be disposed. In Malaysia, the bagasse generated from the processed sugarcane is estimated at about 300 000 tonnes annually (Kamaruzzaman et al., 2000). Some may not realized that these by-products could be an interesting fiber material in making adsorbent like activated carbon. Adsorption medium such as activated carbon has been a popular air cleaner since it's been introduced. Activated carbon can be found in powder or granular form. Activated carbon can be made out of synthetic material or natural material. Oliver et al. (2005) used macroporous styrene/divinylbenzene sulfonic acid ion exchange resin, a type of synthetic activated carbon to treat hydrogen cyanide vapors (HCN) from air. Aguado et al. (2004) used synthetic zeolite membranes to remove indoor air pollutants such as n-hexane, formaldehyde, and benzene. Activated carbon can also be prepared from natural material like agricultural residues such as silk cotton hull, coconut tree sawdust, banana pith, and corn cob (Kadirvelu et al., 2003). Yalçın and Sevinç (2000) had studied the physical characteristic of the activated carbon derived from rice husks. In this work, activated carbon was prepared thermally from a combination of SB and CH to determine its potential for the removal of ammonia gas. Ammonia gas is one of the common types of indoor air pollutants. Exposure of high level of ammonia gas will have an adverse health effect on human especially to our respiratory system. The effectiveness of different mixing ratio of fiber compositions of adsorption medium to ammonia gas removal was investigated. The efficiency of ammonia gas removal by the prepared activated carbon at different concentration was also determined. The Freundlich and Langmuir isotherm models were applied.

1.2 Objective

The main objective is to assess the applicability of the activated carbon prepared from selected agricultural by-products (SB and CH) as adsorbent for ammonia gas. This is achieved through the following specific objectives. The specific objectives are:

1. To determine the physical characteristic and morphological structure of the constructed adsorbing medium.
2. To assess the effectiveness (removal efficiency) of the adsorbing media prepared from different mixing compositions at different ammonia concentrations.
3. To determine the production yield of the adsorbing media, and to estimate production cost of the most effective adsorbing medium from this study.

1.3 Hypothesis

1. The physical properties (surface area, porosity, and volume) changes of the adsorbing medium affect the removal capability.
 - (a) Null hypothesis: there is no difference in removal capability between adsorbing media with different physical properties (surface area, porosity, and volume)
 - (b) Alternative hypothesis: there is a difference
2. Different mixing compositions of adsorbing medium result in changes in removal efficiency at different ammonia concentrations.
 - (a) Null hypothesis: there is no difference in removal efficiency between adsorbing media (different mixing compositions) at different ammonia concentrations.
 - (b) Alternative hypothesis: there is a difference
3. The type of adsorbing medium used results in different yield.
 - (a) Null hypothesis: there is no difference in production yield between adsorbing media used.
 - (b) Alternative hypothesis: there is a difference

1.4 Significance of study

This study will be a significant effort in promoting the green practices. In this study, organic and natural waste materials are used in making adsorbent to be applied in cleaning air pollutants instead of using synthetic or man-made materials. Natural materials have been a better preference over synthetic one since they are environmental-friendly and sustainable. Thus, it indirectly helps in waste minimization.

This study will also be beneficial to many industries such as cleansers-making industry in treating air pollution in the premise. The employment of effective and low-cost adsorbent will certainly be their preferable option in cleaning industrial generated air pollutant like volatile organic compounds. By understanding how efficient the adsorbent removes pollutants from the surrounding atmosphere, it could ensure the quality of air in the industry is good at all times in order to avoid the workforce from being exposed to hazardous gases that is harmful to their health.

Moreover, this research will provide an idea on how to turn one person's trash into another person's treasure. While in this case, AW becomes an asset for certain manufacturing industries, for example adsorbent-making industry. This study will also be helpful to business practitioners who are interested in working with plant-fiber filter media in the area of industrial air treatment. It will definitely serve as a good reference for them on the subject of green practices and air treatment methods in the future.

1.5 Problem statement

Pollution generated from industries contains a wide variety of pollutants and the pollution parameters in the air are very much depending on industry types. Poisonous and foul odors may be produced during the manufacturing process in some industries and consequently, air pollution occurs within the premise and this could cause a depletion of indoor oxygen and the situation will become worse if the factory had bad indoor ventilation. Humans need constant supply of oxygen to stay alive otherwise our life will be affected due to the minimal supply of oxygen in the air.

Ammonia is a weak base and it is found in the emissions from agricultural activities and industry such as fertilizer manufacture. Ammonia is taken into account as one of the hazardous chemicals in the Occupational Safety and Health Act (OSHA), Malaysia because of its corrosive properties in nature. Inhalation of high levels of ammonia gas can have an adverse impact to our human health if constantly exposed to it whether is in the indoor or outdoor environment.

Air pollutants can be removed by a combination of treatment methods. Filtration is an important preliminary treatment process in a typical air pollution treatment system. Types of filter media employed in the filter are crucial in order to remove unwanted pollutants in the air effectively. Nowadays, all kind of synthetic adsorbents are used as filter media because they are effective, durable and versatile. Various adsorbents existed in the market and silica gel, activated carbon and zeolites are some of the examples of adsorbents. Adsorbents are also expensive and require constant maintenance due the usage of relatively expensive starting material.

Being economic definitely is one of the factors to be considered in selecting an adsorbent. Activated carbon derived from agricultural by-products, such as SB and CH is a relatively low-cost adsorbent which makes it a popular demand to be used for application concerning air pollution treatment. In addition, plant-fiber based adsorbents are much more sustainable, environmentally-friendly, inexpensive, easily obtained, and easily disposed off.

Agricultural plants are cultivated commercially due to the elevating demand in the global market. Consequently, this activity also leads to large production of AW. In Malaysia, the annual production of total AW is approximately 42 million tonnes and crop residues (CR) accounted for about 71.4% of the total amount which is 32 million tonnes (UNESCA, 2000). CR mainly consists of hemicellulose, cellulose, and lignin. Naturally, AW is biodegradable on land and thus can serve as natural fertilizer to the soil. However, if AW were poorly managed, it can bring harm to the environment and human health, for example the abundance of AW can become a breeding site for vectors such as rats, mice, flies, mosquitoes, and cockroaches. This will eventually increase the chances of disease spreading by these vectors to human. Burning the AW does not solve the problem at all; in fact, it only worsens the situation by introducing more air pollutants into the atmosphere. AW may also clog water from flowing when rain flushes them into the waterways. Disposing of AW will certainly put additional pressure to open landfill by occupying more space and area. Converting the AW to activated carbon will be able to solve some of problems or issues regarding to solid wastes management and treatment in the country.

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