AIR POLLUTION CONTROL USING *HIBISCUS CANNABINUS L.* (KENAF) TO REDUCE AIR POLLUTANTS

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AIR POLLUTION CONTROL USING HIBISCUS CANNABINUS L. (KENAF) TO REDUCE AIR POLLUTANTS

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Thesis submitted in fulfillment of the requirements
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ABSTRAK

Pelepasan unsur-unsur yang merosakkan dari sisa tambang melibatkan banyak kesan alam sekitar. Pelupusan buangan lombong yang tidak terkawal berlaku boleh dikaitkan dengan peningkatan kekeruhan dalam perairan yang menerima atau dengan pembebasan unsur-unsur yang berpotensi merusak, keasidan atau radioaktif. Bahan pencemar ini boleh merebak ke pedosphere, biosfera, atmosfera dan hidrosfera dan menyebabkan kesan alam sekitar. Peleburan bauksit ke sumber air menyebabkan kesuburan tanah yang dikurangkan serta mempengaruhi produk makanan pertanian dan kehidupan akuatik. Pendedahan pekerjaan bauksit memberi kesan kepada kesihatan pelombong, dan mempunyai kesan negatif terhadap kesihatan masyarakat sekitar, seperti peningkatan gejala pernafasan, pencemaran air minuman, risiko kesihatan yang berpotensi lain daripada pengambilan bauksit dan logam berat, termasuk kehilangan pendengaran yang disebabkan oleh bunyi dan tekanan mental. Dalam kajian ini, *Hibiscus Cannabinus L.* (Kenaf) digunakan untuk ujian untuk mengatasi masalah pencemaran udara. Menurut Buku Panduan Pengeluaran Kenaf: Fiber, Feed, and Seed Retrieved, ia boleh dibuat sebagai penyerap, tekstil, makanan ternakan dan serat dalam plastik baru dan kitar semula. Prototaip telah dipasang dengan menggunakan papan Akrilik dalam dimensi 1000 * 500 * 500mm. Eksperimen kawalan dijalankan di mana kemudian bauksit diletakkan di bahagian bawah prototaip dan kelajuan angin yang berlainan telah digunakan ke dalam sistem. Pekatan bahan-bahan itu dikesan dari kit pemantauan rasa langsung dan sampler udara detektif debu. Dalam keadaan tahap kelajuan angin 3, kepekatan purata PM_{10} dikurangkan secara berterusan kerana ketebalan serat kenaf meningkat. Pengurangan kepekatan PM10 adalah dari 0.028mg / m^3 kepada 0.021mg / m^3, 0.014mg / m^3 dan 0.012mg / m^3 dengan satu lapisan, dua lapisan dan tiga lapisan gentian kenaf. Kecekapan pengurangan kepekatan PM_{10} dinaikkan kerana ketebalan gentian kenaf meningkat. Kecekapan pengurangan maksimum adalah 57.1% untuk PM_{10}. Ia dapat menyimpulkan bahawa kenaf mempunyai keupayaan dalam mengurangkan perkara tertentu. Selanjutnya, apabila kelajuan angin meningkat, kepekatan pencemaran udara meningkat. NH_3 mempunyai kepekatan tertinggi sebanyak 0.367 ppm pada kelajuan angin tertinggi di kalangan PM_{10}, Cl_2 dan NO_2. Ini dapat disimpulkan bahawa sampel bauksit mengandungi ammonia yang tinggi berbanding dengan bahan lain. Selain itu, juga dapat disimpulkan bahawa angin membantu mengaktifkan zarah-zarah udara yang berbahaya untuk tersebar ke udara atau alam sekitar. Secara keseluruhannya, *Hibiscus Cannabinus L.* (Kenaf) boleh digunakan dalam sistem penapisan udara atau bertindak sebagai rawatan udara untuk mengurangkan zarah-zarah berbahaya yang terdapat dalam alam sekitar. Ia juga tidak mahal dan mudah didapati di Malaysia.

ABSTRACT

Release of destructive elements from mine waste associated many of environmental impacts. Uncontrolled disposal of mine wastes occurs can be associated with increase turbidity in receiving waters or with the release of significant quantities of potentially destructive elements, acidity or radioactivity. These contaminants may spread to the pedosphere, biosphere, atmosphere and hydrosphere and cause environmental effects. Bauxite leaching into water sources resulting in reduced soil fertility as well as affecting agricultural food products and aquatic life. Bauxite occupational exposure affects the health of miners, and has negative consequences on the health of surrounding communities, such as increased respiratory symptoms, contamination of drinking water, other potential health risks from ingestion of bauxite and heavy metals, including noise-induced hearing loss and mental stress. In this research, *Hibiscus Cannabinus L.* (Kenaf) was used for test in order to overcome the air pollution problems. According to Handbook of Kenaf Production: Fiber, Feed, and Seed Retrieved, it can be made as adsorbents, textiles, livestock feed and fibers in new and recycled plastics. A prototype was assembled by using Acrylic board in dimension of 1000*500*500mm. A control experiment was conducted where a later of bauxite was put in the bottom of the prototype and different wind speeds was applied into the system. The concentrations of the substances were detected from the direct sense monitoring kit and dust detective air sampler. In condition of wind speed level 3, the average concentration of PM_{10} was reduced continuously as the thickness of kenaf fiber increased. The reduction of concentration of PM_{10} was from 0.028mg/m3 to 0.021mg/m^3, 0.014mg/m^3 and 0.012mg/m^3 with one layer, two layers and three layers of kenaf fiber respectively. The PM_{10} concentration reduction efficiency was raised as the thickness of kenaf fiber increased. The maximum reduction efficiency was 57.1% for PM_{10}. It can conclude that the kenaf has the ability in reducing the particular matter. Furthermore, As the wind speed increased, the concentration of air pollutants increased. NH3 has the highest amount of concentration of 0.367ppm at the highest wind speed among PM_{10}, Cl_2 and NO_2. This can be concluded that the bauxite sample contained high amount of ammonia as compared to the other substances. Besides that, it also can be concluded that wind helped in activated the harmful air particles to dispersed into the air or environment. In overall, *Hibiscus Cannabinus L.* (Kenaf) can be applied in air filtration system or acts as air treatment in order to reduce the harmful particles that present in the environment. Its also not expensive and easy available in Malaysia.

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LIST OF SYMBOLS

%	Percentage
Mt	Million metric tons
t	Metric tons
mg/L	Milligram per litre
µg/m3	Microgram per meter cube
µm	Micrometer
mg/m3	Milligram per meter cube
ng/m3	Nanogram per meter cube
cm	Centimeter
mg/kg	Milligram per kilogram
g/cm	Gram per centimeter
MPa	Mega pascal
mm	Millimeter
ppm	Parts per million

LIST OF ABBREVIATIONS

GDP	Gross Domestic Product
WHO	World Health Organization
PM	Particulate Matter
NH_3	Ammonia
NOx	Nitric Oxide
NO_2	Nitrogen Dioxide
N_2O	Nitrous Oxide
N_2O_3	Dinitrogen Trioxide
N_2O_4	Nitrogen Tetroxide
N_2O_5	Dinitrogen Pentaoxide
Cl_2	Chlorine
CO	Carbon Monoxide
CO_2	Carbon Dioxide
SO_2	Sulfur Dioxide
SOx	Sulphur Oxides
SO_3	Sulfur Trioxide
SO_4	Sulphate
S_2O_3	Thiosulfate
H_2SO_4	Sulphric Acid
VOCs	Volatile Organic Compounds
NMVOCs	Non-Methane Volatile Organic Compounds
CNS	Central Nervous System
CH_4	Methane
O_3	Ozone
UV	Ultraviolet Radiation
O	Monoxide
O_2	Oxygen
O_3	Ozone
CFC	Chlorofluorocarbon
Pb	Lead
HC	Hydrocarbon
PAN	Peroxyacytyl Nitrate
$Al(OH)_3$	Aluminum Trihydrate
Al_2O_3	Aluminium Oxide

$NaAlO_2$	Sodium Aluminate
NaOH	Sodium Hydroxide
H_2S	Hydrogen Sulfide
API	Air Pollution Index
C	Control Experiment
conc.	Concentration

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Malaysia had identified mineral resources of barite, bauxite, clays, coal, copper, gold, iron ore, limestone, natural gas, petroleum, silica, and silver. After many years of exploitation, however, such minerals as barite, copper, and limenite were depleted. During the 20th century, mineral production played an important role in Malaysia's national economy. In 2014, Malaysia's real gross domestic product (GDP) increased by 6.0% compared with an increase of 4.7% in 2013 and an increase of 5.6% in 2012. An increase in domestic demand and growth in the country's exports contributed to economic growth. The output of the mining and quarrying sector increased by 3.1% in 2014 compared with increases of 0.7% in 2013 and 1.0% in 2012. The rate of growth in the manufacturing sector increased by 6.2% in 2014 compared with increases of 3.5% in 2013 and 4.8% in 2012. The rate of growth in the construction sector increased by 11.6% in 2014 compared with increases of 10.9% in 2013 and 18.6% in 2012. The mining and quarrying activity accounted for 7.9% of the country's real GDP. (The Mineral Industry of Malaysia, 2017).

Malaysia is endowed with over 33 different mineral types, comprising metallic, non-metallic and energy minerals, worth several billion dollars in economic potential. Bauxite is one of the metallic mineral sub-sector produce in Malaysia. In early 1970s, bauxite and copper contribute to the mining sector. According to the Malaysian Chamber of Mines, bauxite was produced in Malaysia from a mine located in the State of Johore. Production of bauxite in 2014 was estimated to be 3.26 million metric tons (Mt) compared with 208,770 metric tons (t) in 2013 and 121,873 t in 2012. All the production was exported to the other Asian countries. Malaysia's remaining bauxite reserves were small, but bauxite resources were recently discovered in the States of

Sabah and Sarawak. In 2014, Malaysia exported about 3.7 Mt of bauxite and imported 11,184 t of bauxite compared with exports of 17,422 t and imports of 5,221 t in 2013. Because Indonesia banned exports of bauxite early in the year, Malaysia became an important bauxite supplier to China. Demand for Malaysian bauxite in international markets was expected to continue to increase (U.S. Geological Survey, 2014).

Table 1.1 World Bauxite Mine Production Year 2018

Countries	**Bauxite (tons)**
Year	**2008**
Australia	61,389,000
Bosnia and Herzegovina	860,000
Brazil	22,000,000
China	35,000,000
Dominican Republic	400,000
Ghana	700,000
Greece	2,220,000
Guinea	18,500,000
Guyana	2,098,000
Hungary	550,000
India	21,210,000
Indonesia	1,400,000
Iran	500,000
Jamaica	14,000,000
Kazakhstan	4,900,000
Malaysia	140,000
Montenegro	672,000
Mozambique	9,000
Pakistan	8,000
Russia	6,300,000
Sierra Leone	954,000
Suriname	5,230,000
Tanzania	5,000
Turkey	350,000
United States	NA
Venezuela	5,500,000
Vietnam	30,000
Total	205,000,000

Source: E. Lee Bray (2010).

Table 1.2 World Bauxite Mine Production

Countries	Bauxite (tons)	
Year	**2015**	**2016**
United States	W	W
Australia	80,900,000	82,000,000
Brazil	33,900,000	34,500,000
Canada	-	-
China	65,000,000	65,000,000
Greece	1,820,000	1,800,000
Guinea	18,100,000	19,700,000
Guyana	1,700,000	1,600,000
India	23,800,000	25,000,000
Indonesia	202,000	1,000,000
Ireland	-	-
Jamaica	9,630,000	8,500,000
Kazakhstan	4,680,000	4,600,000
Malaysia	35,000,000	1,000,000
Russia	5,900,000	5,400,000
Saudi Arabia	1,600,000	4,000,000
Spain	-	-
Suriname	1,600,000	-
Vietnam	1,150,000	1,500,000
Other countries	7,580,000	6,860,000
World total (rounded)	293,000,000	262,000,000

Source: E. Lee Bray (2017).

As compare Table 1.1 and Table 1.2, in 2015, the production of bauxite was increased 250 times of the bauxite production in 2008. In 2016, as shown in Table 1.2 global bauxite production decreased by 11% owing to reduced production of 34 million tons in Malaysia. The Government of Malaysia continued its ban on bauxite mining through at least year end 2017 but did permit exports of stockpiled bauxite. The ban was imposed in January 2016 because of concerns about pollution from mines and uncovered stockpiles at ports (U.S. Geological Survey, 2018).

Release of destructive elements from mine waste associated many of environmental impacts. Uncontrolled disposal of mine wastes occurs can be associated with increase turbidity in receiving waters or with the release of significant quantities of potentially destructive elements, acidity or radioactivity. These contaminants may spread to the pedosphere, biosphere, atmosphere and hydrosphere and cause environmental effects (Lottermoser,2007). Bauxite leaching into water sources resulting in reduced soil fertility as well as affecting agricultural food products and aquatic life. Bauxite occupational exposure affects the health of miners, and has negative consequences on the health of surrounding communities, such as increased respiratory symptoms, contamination of drinking water, other potential health risks from ingestion of bauxite and heavy metals, including noise-induced hearing loss and mental stress (Lee et al., 2017).

1.2 Problem Statement

. Malaysian miners become world's top bauxite producer after Indonesia stopped producing and exporting bauxite ores to China. Pahang province has been affected by open-cast bauxite mining for months and become a contentious issue. Felda Bukit Goh, Gebeng Kuantan is the most popular bauxite excavation area. Crucial impact turn out to the serving community due to the unregulated bauxite mining. Out of 236 active mine sites, only 36 are legal (Azza Nurshafira, 2017). Much of the mining environmental issues are related with the release of destructive elements from the waste of mine.

Felda Bulit Goh is an active bauxite mining activities area for past few years and most of it are illegal mining. This brings a lot of impacts not only on environment but also socioeconomic and health. For environmental, there is potential to contaminate drinking water due to bauxite mining. Bukit Goh, Bukit Sagu, Bulit Ubi and Semambu Water Treatment Plant are the water treatment plants located at the area of bauxite mining in Kuantan. The mining activities have potentials to contaminate the sources of drinking water as the water treatment plants are placed at downstream. On 29 December 2015, Bukit Goh Water Treatment Plant was closed once because of the severe pollution in Sungai Riau (Noor Hisham et al., 2016). Water samples taken from nearby residences have exceeded the Health Ministry's aluminium levels of 0.20mg/L while mercury levels were 0.0093mg/L, nine times above the recommended level for raw water. However, continuous drinking water monitoring by Pahang State Health Department has reported that the concentration of aluminium and iron in drinking water has yet to exceed the National Drinking Water Quality Standard (Abdullah N et al., 2016).

Figure 1.1 Bauxite washing pond showing “red water”

Source: Noor Hisham et al. (2016).

Figure 1.2 Water from the pond were discharged into Sungai Riau

Source: Noor Hisham et al. (2016).

Figures 1.1 and 1.2 show a bauxite washing pond whereby the effluent water were discharge into Sungai Taweh which flows downstream causing severe pollution to Sungai Riau. Contamination of water by bauxite mining has the potential to caused harm due to components such as iron, aluminium as well as other toxic heavy metals found in trace amounts (Petavratzi E KS & Lowndes I., 2005). Acidic water produced from bauxite mining increase the heavy metal solubility and damage the aquatic ecosystems, especially at pH 5 and below. Agricultural and industrial activities, land filling and mining cause heavy metals introduced to groundwater and impacting drinking water and irrigation sources (HB B., 2005).

For health impacts, trend of asthma and upper respiratory infection increased during 2015 as compared to the year before in Kuantan. According to local 24-hour, at the same period, PM_{10} levels ranging from 164 to 277µg/m^3 which exceeding the Malaysian National Ambient Air Quality Standards 2015 (Abdullah N et al., 2016).

Furthermore, noise pollution also an impact cause by bauxite mining. Noise-induced hearing loss, hearing sensitivity loss and sleep disturbances are the potential health effects. Noise has been associated with cardiovascular and physiological effects along with behavioral and cognitive impacts (Abdullah N et al., 2016).

Bauxite mining repercussions on the environment through destructive of ecosystem. Therefore, a detailed research is required to study which to implement measures to control and manage impacts of bauxite mining on the environment and human health. *Hibiscus Cannabinus L.* (Kenaf) fiber was introduced in this study as natural air filter. This research had been conducted to filter the air pollutants that produced from bauxite mining activities such as transportation and stockpile by using *Hibiscus Cannabinus L.* (Kenaf) fiber.

1.3 Objectives

The objectives of this research are as follows:

i. To study the reduction of air pollutants concentration by using different thickness of *Hibiscus Cannabinus L.* (Kenaf) and the influence of wind speed.

ii. To propose the safe environment index for different thickness of *Hibiscus Cannabinus L.*(Kenaf) in air pollutants reduction.

1.4 Scope of Study

The scope of this study is to investigate the process to reduce the air pollutants from bauxite mining and it's effectiveness by using *Hibiscus Cannabinus L.* (Kenaf). A test with proposed wind speed and Kenaf fiber was used to applied above the bauxite sample will be conducted. five pollutant parameters (particulate matter (PM_{10}), ammonia (NH_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and chlorine (Cl_2) will be tested by using Kenaf fiber and repeating the process with different thickness of Kenaf fibre to observe the effect. A safe environment index for different thickness of *Hibiscus Cannabinus L.*(Kenaf) in air pollutants reduction will be develop at the end of the test.

1.5 Significance of Study

The significance of study for this research is to improve the air quality of Kuantan area that polluted by mining activities. Firstly, kenaf has high accessibility where it is easily growing plant and it is environmental friendly. Therefore, kenaf fiber is economical friendly due to it low cost. The significance of using kenaf fiber is the quality of air is better as compared to the quality of air without using kenaf fiber to filter the air. Kenaf fiber can reduce the harmful gases or particulate matter that present in the air, in the sense that, it can reduce the illness or disease caused by the harmful gases or particular matter in the air.

Further research or development of using kenaf fiber is a new marketplace and a way to control the air quality. In this research, kenaf fiber has a wide application and contribution such as it can applied as filtration system to provided a better quality of air by reducing the harmful particles. Next, it can also applied on the stockpile of bauxite to reduce the emission of air pollutants to the atmosphere. Transporting bauxite also an issues that cause air pollution, hence, kenaf fiber can be applied on the lorry that transports bauxite. This also help in minimize the reddish situation on road and infrastructure.

Last but not least, this research advocate the consciousness of the air quality control and also the uniqueness of plant that can be further applied for other usage.

CHAPTER 2

LITERATURE REVIEW

2.1 Air Pollution

Air pollution is the presence in the atmosphere of substances that occur naturally or put there by the acts of man in concentrations sufficient to interfere with health, comfort, safety, full use and enjoyment of property. Air pollution is a common issue and topic for public as no one can escape from the air pollution that caused by natural and human's activities, which can be divided into stationary and mobile sources such as combustion of fossil fuels from industries, power generation and vehicles (Armenta and de la Guardia, 2016).

There are many sources that result in pollution of air either from natural or human actions. Natural radioactivity, organic compounds evaporation, wind erosion, forest fires are some of the natural activities or events that pollute the air. Sources of air pollution refer to the various locations, activities or factors which are responsible for the releasing of pollutants into the atmosphere (Mahendra Pratap Choudhary and Vaibhav Garg, 2013).

Air pollution are essentially subject to the impacts of emission sources and regional transport characteristics in addition to the atmospheric diffusion capacity which is primarily related to meteorological conditions (Giorgi, F.; Meleux, F,2007). Besides that, atmospheric stability and topography also the factors that affecting the level of air pollution. The example of meteorological elements including wind speed, temperature, relative humidity, and precipitation (Zhang, L.,2013).

2.1.1 Type of air pollutants

Pollutant of air is known as a substance presence in the air that can be adverse to the environment and humans. It can be in the form of solid particles, liquid droplets or gases state that caused by natural or man-made. They are two categories of pollutants which are primary pollutants and secondary pollutants. Primary air pollutant defined as the pollutant enters directly into the atmosphere from natural events or human activities such as from a volcanic eruption, motor vehicle that exhaust the carbon monoxide gas (CO) or factories that released the sulphur dioxide (SO_2). Other than CO and SO_2, carbon dioxide (CO_2), nitric oxide (NO), most hydrocarbon and most particulates also consider as primary air pollutants. For secondary air pollutant, it is formed in the atmosphere through chemical reaction, solar reaction and also by hydrolysis or oxidation. Ground level ozone that make up photochemical smog is an example of secondary air pollutant.

2.1.1.1 Sulphur Oxides (SOx)

Oxides of sulphur are colourless, non-flammable and non-explosive gas with a suffocating odor. It is a chemical compound with the formula SO_2. SO_2 is produced by volcanoes and in various industrial processes. SO, SO_2, SO_3, SO_4 and S_2O_3 are some of the compound gaseous. SO_2 and SO_3 are most interest in the study of air pollution. Further oxidation of SO_2, usually in the presence of a catalyst such as NO, forms H_2SO_3 and thus acid rain which is one of the causes of concern over the environmental impact of the use of these fuels as power sources.

2.1.1.2 Nitrogen Oxides (NOx)

Nitrogen oxides are important ambient air pollutants which may increase the risk of respiratory infections (Adel Ghorani-Azam et al, 2016). They are mainly emitted from motor engines and thus are traffic-related air pollutants. NO, NO_2, N_2O, N_2O_3, N_2O_4 and N_2O_5 are the example for oxides of nitrogen. The primary concerns in the air pollution are NO and NO_2 as they are emitted in significant quantities to the atmosphere especially NO_2 expelled from high temperature combustion and also produced naturally during thunderstorms by electric discharge. It is one of the most prominent air pollutant.

2.1.1.3 Carbon Monoxide (CO)

Oxides of carbon is an anthropogenic source from motor vehicles, fossil fuel burning for electricity and heat, industrial processes and also solid waste burning. The incomplete combustion or oxidation of carbon results in production of colourless and odorless carbon monoxide, CO. A research found that the affinity of CO to hemoglobin as an oxygen carrier in the body is about 250 times greater than that of oxygen (Adel Ghorani-Azam et al, 2016). Depending on CO concentration and length of exposure, mild to severe poisoning may occur.

2.1.1.4 Volatile Organic Compounds (VOCs)

VOCs are an important outdoor air pollutant and they are often separated into methane (CH4) and non-methane (NMVOCs) categories. Methane is an extremely efficient greenhouse gas which contributes to enhanced global warming. Other hydrocarbon VOCs are also significant greenhouse gases via their role in creating ozone and in prolonging the life of methane in the atmosphere although the effect varies depending in local air quality.

2.1.1.5 Particular matters (PM)

PM are dispersed matter of solid or liquid suspended in a gas. The size of PM is vary which mostly from 2.5 to 10μm (PM2.5 to PM10). the size of particle pollutants is directly associated with the onset and progression of the lungs and heart diseases. The sources of particulates can be man-made or natural. The typical PM are dust, smoke, fumes, fly ash, mist and spray. Long-term exposure to current ambient PM concentrations may lead to marked reduction in life expectancy. Symptoms of exposure may include persistent cough, sore throat, burning eyes and chest tightness. It also trigger asthma or lead to premature death, particularly in elderly individuals with pre-existing disease (Ostro B et al, 2011).

Atmospheric particles have acknowledge as a detriment to air quality (Larson et al., 1989), human health (Solomon *et al*., 2012), and climate (Boucher *et al*., 2013). PM mass is adjusted by the Environment Protection Agency according to the size and air concentration and is subject to National Ambient Air Quality Standards (NAAQS) in the USA. (Chow *et al*., 2015). USA is also well-known for the spatial and temporal variability in the size, morphology, and chemical composition of PM in regions, counties and states (Solomon *et al*., 2012). It has been acknowledged that such variability may result in variation in health effects resulting from exposure to PM (Solomon *et al.,* 2012). Recently, there is important evidence is developing regarding the association between exposure to organic carbon emissions and health effects (Solomon *et al.,* 2012). Hence, accurate characterization of the organic chemical composition of PM is essential to epidemiological studies that seek to identify associations between exposure to such chemicals and resultant health effects.(Lynam *et al.,* 2017)

One of the important component of PM2.5 is carbon which consist of about 30 to 50% of the PM2.5 mass concentration. It is monitored at supersites in the USA (U.S. EPA TTN 2017). There are elemental carbon (EC) and organic carbon (OC) fractions which is include in the carbon fraction of PM2.5. It is also known to be released from various sources such as fossil fuel combustion, meat cooking, biomass burning and mobile sources (Schauer *et al*., 1996) as well as produced in the atmosphere via chemical oxidation of gas phase precursors (Heo *et al.,* 2013). Carbonaceous emissions have been associated with adverse respiratory, cardiac, mutagenic, and carcinogenic health outcomes (Solomon *et al*., 2012). In particular, the OC component, which is much larger than the EC component (Solomon *et al*., 2012), consists of both primary (POA) and secondary (SOA) organic aerosols (Lewandowski *et al.,* 2008; Heo *et al*., 2013).

Particulate matter consists of combination of soot and other partial solid and liquid phase materials. There are two types of particulate matter in general which is soluble and insoluble organic fraction. Fuel rich regions at temperature without sufficient oxygen concentration will leads to soot formation. Hydrocarbons and liquid phase materials are absorbed on the surface of soot but it is all depending on the engine operating conditions as shown in Figure 1. PM is almost 50% composed of soot. On the other hand, particles such as aldehydes, alkanes, alkenes, aliphatic hydrocarbon are included in the soluble fraction. A lots of different constituents such as lubricating oil, partially oxidized fuel and oil also contribute to a soluble organic fraction in particulate matter. (Lewandowski *et al*., 2008; Heo *et al*., 2013).

There are a certain size range of particulate matters, most of it size range from 7.5 to 1.0 μm. This size factor is considered as an important factor in health aspects. If the size is tiny then it is more likely to be inhaled by human beings easily. Those tiny particles are also going to trapped in the bronchial passages and alveoli of the lungs. Almost 90% of the particulates are emitted from fuel burning engine are in size range <50nm which is considered tiny particle. Particulate mass lies in the accumulate mode range is that is 50mm< D <1000nm. The diesel engine at a temperature between about 1000 and 2800 K, at a pressure of 50-100 atm can contribute to soot formation. By adopting soxhlet and sonification methods the soluble organic fraction can be extracted. Full extraction requires different solvents, since the particulates are mixtures of polar and non-polar components. To remove soluble organic fraction and soot, extractants such as methylene chloride, dichloromethane and benzene-alcohol mixture are the most commonly used. (Mohankumar *et al.,* 2017)

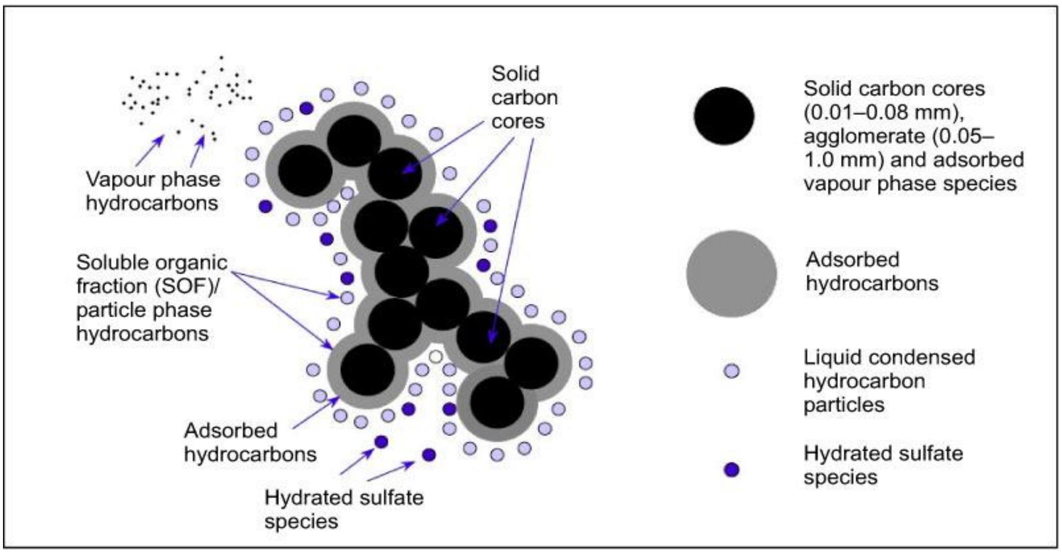

Figure 2.1 Schematic representation of particulate matter

Sources: (Mohankumar et al., 2017)

2.1.1.6 Ozone (O_3)

O_3 is a colourless gas which is the major constituent of the atmosphere and it is found both at the ground level and in the upper regions of the atmosphere which called troposphere. O_3 is a naturally occurring gas in the stratosphere where at this region, it protects humans from sun's harmful ultraviolet radiation (UV). It is created when UV strikes the stratosphere and dissociating or splitting oxygen molecules (O_2) to atomic oxygen (O). O is then quickly combined with further oxygen molecules and form O_3. Ozone depletion in he stratosphere is caused by Chlorofluorocarbon(CFC) as propellant, halons, methyl chloroform and carbon tetrachloride. Ozone induces a variety of toxic effect in humans and experimental animals at concentration that occur in many urban areas (Lippmann M., 1989).

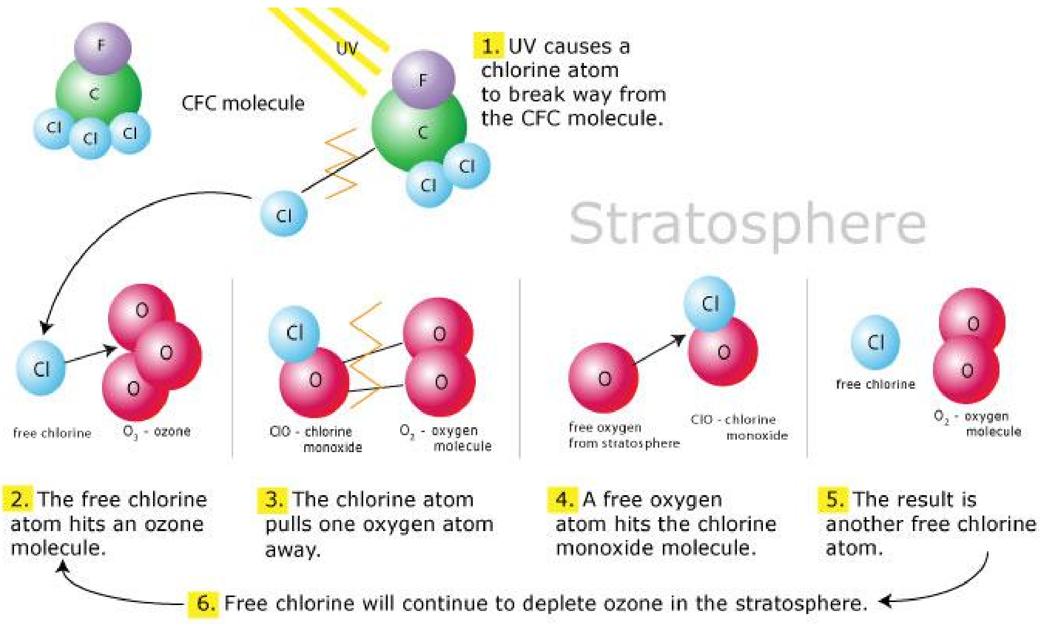

Figure 2.2 Process of ozone depletion that result in air pollution
Source: Sierra-Vargas et al. (2012).

In Table 2.1, the standard level of some conventional air pollutants is presented in which the values were defined as air quality standards that provide public welfare protection. Air pollution levels are given as the average of the air pollutant concentrations measured at site for a long periods of time(Pires et al., 2016).

Table 2.1 The standard level of some conventional air pollutants

Air pollutants	Major source	Averaging time	Standard level	Health impact
$PM_{2.5}$ PM_{10}	Motor engines, industrial activities, smokes	24h 24h	35μg/m^3 150μg/m^3	Respiratory and cardiovascular diseases, CNS and reproductive, dysfunctions, cancer
O_3	Vehicular exhaust, industrial activities	1h	0.12mg/m^3	Respiratory and cardiovascular dysfunctions, eye irritation
CO	Motor engines, burning coal, oil and wood, industrial activities, smokes	1h	35mg/m^3	CNS and cardiovascular damages
SO_2	Fuel combustion, burning coal	1h	75μg/m^3	Respiratory and CNS involvement, eye irritation
NO_2	Fuel-burning, vehicle exhaust	1h	100μg/m^3	Damage to liver, lung, spleen and blood
Pb	Lead smelting, industrial activities, leaded petrol	3 months average	0.15μg/m^3	CNS and hematologic dysfunctions, eye irritation
HC	Fuel combustion, wood fires, motor engines	1 year	1ng/m^3	Respiratory and CNS involvement, cancer

Source: Adel Ghorani-Azam (2016).

2.1.2 Phenomena of Air Pollution

Acid deposition is one of the phenomena of air pollution. Mild sulphuric or nitric acid produced when emissions of sulphur oxides and nitrogen oxides combined with sunlight and water vapour. Acid deposition occurs when pH level falls below 5.6 and it caused damage on materials such as buildings, metals car paints and etc. It also destroys aquatic life due to acid rain fall in to the rivers or seas. Furthermore, it caused leaching of soil nutrients and also leaching of toxic metal such as copper and lead from pipes into drinking water which may cause aggravates respiratory illness.

The development of photochemical smog which also an air pollution phenomena is directly related to automobile use and sunlight. It is a mixture of pollutants such as particulates, nitrogen oxides, ozone, aldehydes, PAN, hydrocarbon and etc. The photochemical smog can caused respiratory illness, throat, eye and nose irritation as well as inhibit growth of plant. Another phenomena are haze and greenhouse effect. Haze is a form of air pollution which is exacerbated at certain times of the year under specific weather conditions. The presence of a large number of minute particles suspended in the atmosphere caused by natural in origin or from human activities. Whereas, greenhouse gases make changes in the climate which leads to increase evaporation and also more condensation.

2.1.3 Effects of air pollution

2.1.3.1 Health effect

The airways are a point of entry for pollutants which in turn may cause lung disease. The human health effects of poor air quality are far reaching but principally affect the body's respiratory system and cardiovascular system. For example, PM may deposited into any of the three respiratory compartments: the extrathoracic, tracheobronchial and alveolar regions as the Figure 2.1 shown. Individual reactions to air pollutants depend on the type of pollutant a person is exposed to, the degree of exposure, the individual's health status and genetics.

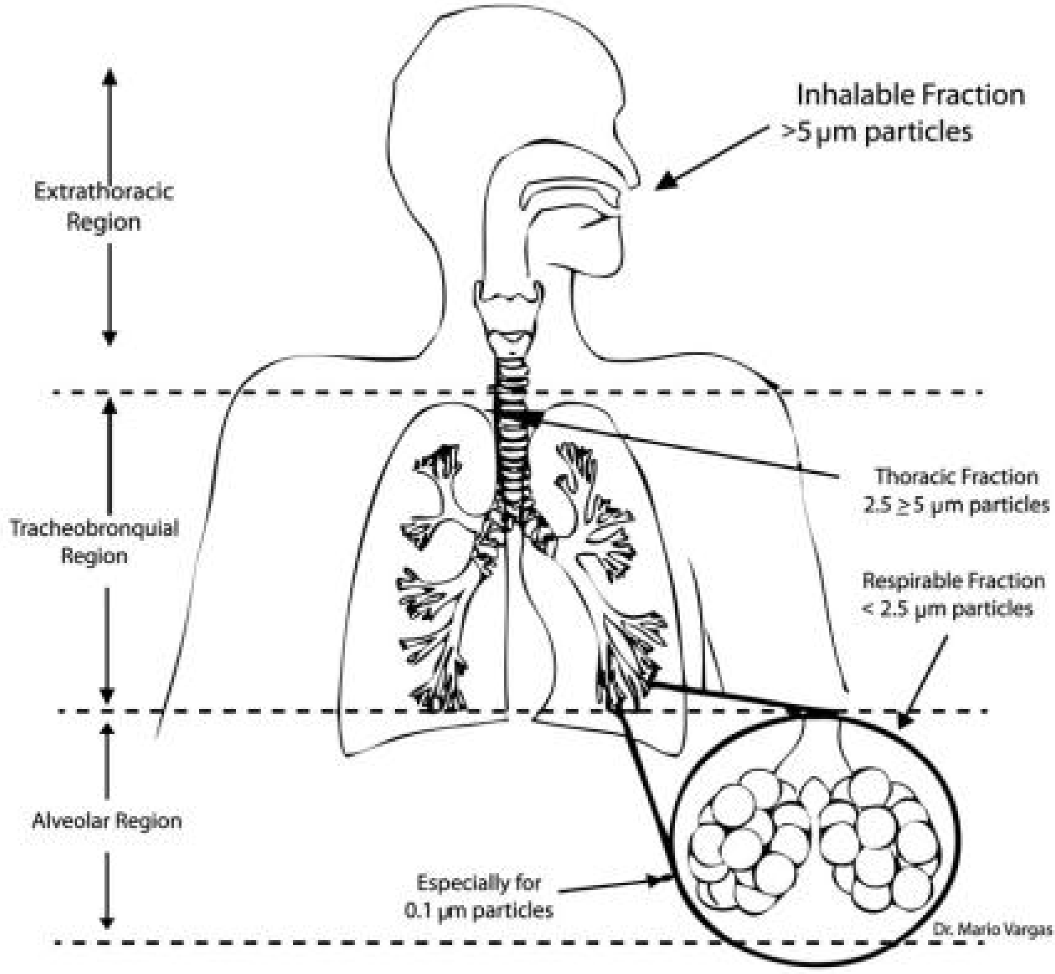

Figure 2.3 Regional deposition of particles in the human respiratory tract

Source: Respirology (2012).

2.1.3.2 Environmental effect

Ecologically, air pollution can cause serious environmental damages to the groundwater, soil, and air (Mellouki A et al.,2016). Poisonous air pollutants or toxic chemicals in the air can form acid rain. It can also form dangerous ground level ozone. These destroy plant, crops, farms, animals and continue to make water bodies harmful to humans and animals that live and depend on water.

2.1.3.3 Economic effect

The effects of air pollution on the economy may be a derived one. In simple language, the economy thrives when people are healthy and business that depends on cultivated raw materials and natural resources are running at full efficiency. Air pollution reduces agricultural crop and commercial forest yields by billions of money each year. This in addition to people off work for health reasons can costs the economy greatly.

2.2 Bauxite mining

Bauxite, named after the locality Les Baux in the south of France, is mainly composed of hydrous aluminium oxides, iron and titanium oxides, quartz and other silicate species (Knorr and Karsten, 2008). Bauxite is the primary source for industrial aluminium production. It contains mixtures of various minerals such as gibbsite, boehmite, hematite, goethite, Al-goethite, anatase, rutile, ilmenite, kaolin, and quartz. The suitable condition for the origin of bauxite is warm and humid climate where this condition refers to the countries located in low-latitude tropical or equatorial regions such as Africa, South Asia and Australia (Monsels and van Bergen, 2017).

2.2.1 Process of bauxite mining

The bauxite ore contains aluminum trihydrate ($Al(OH)_3$) will be treated to produce aluminium oxide, Al_2O_3 through alumina refining from the bauxite ore by exploiting the reversible reaction of the Bayer process. The reaction is firstly driven in the sodium aluminate ($NaAlO_2$) direction by the addition of caustic soda (NaOH) to bauxite. Bauxite residues are then removed, leaving the process liquid, termed "green liquor." The reaction is then driven back in the opposite direction during precipitation, to produce crystals of aluminum trihydrate, which are then calcined to produce anhydrous aluminum oxide (alumina). The "spent liquor" leaving precipitation returns to the beginning of the refinery circuit(A. Michael Donoghue et al., 2014) . A typical process flow for bauxite mining was shown in Figure 2.2.

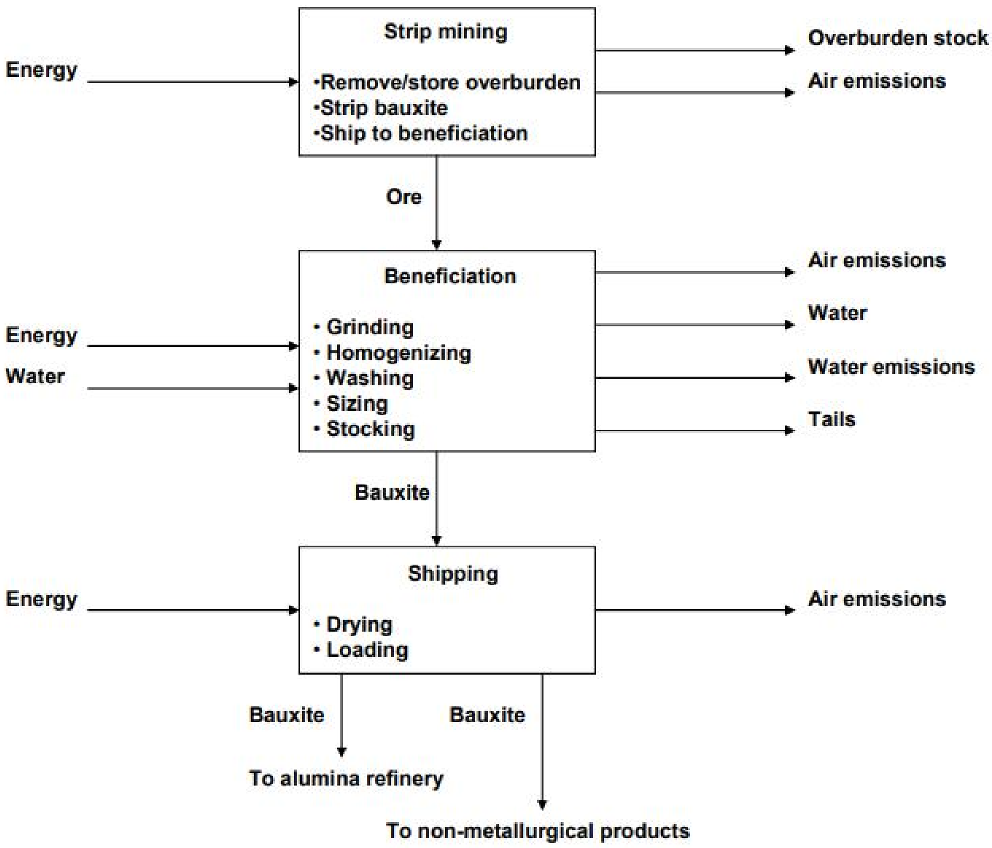

Figure 2.4 Process of bauxite mining

Source: Alcoa Inc. (2009).

2.2.2 Effects of bauxite mining

Aggressive mining activities has caused serious problems towards human and environment in many aspect such as air pollution, water pollution, soil pollution, noise pollution and etc. Table 2.2 shows the type of environmental pollution caused in bauxite mining.

Table 2.2 The type of environmental pollution caused in bauxite mining

Type of pollution	Descriptions	References
Air pollution	-Dust emissions (large particles ranging 1-10µm, fine particles ranging 0.1-1µm) leading to cardiovascular and respiratory problems.	Gelencser A KN et.al.
Water pollution	-Leaching of iron, aluminium, arsenic, cadmium, lead, nickel, manganese and mercury into drinking water source. -High concentration of heavy metals in sediments, which are deposited in water, further dissolves and deposits into fish and benthic invertebrates, in which levels are 10-1000 higher than in normal water.	Petavratzi E KS et.al. Yi YJ et.al.
Soil pollution	- Soil contamination of heavy metals decrease microbial activities which lowers its fertility. - Insufficient soil depth for agriculture (<15cm). - Habitat destruction and soil erosion.	Raymond AW FE et.al. Lad RJ et.al. Mertzanis A et.al.
Food contamination	- Lead, cadmium, arsenic accumulation in vegetables. - High levels of lead found in sweet potato, exceeding CODEX safety limit of 0.1 mg/kg.	Zhou H et.al. Wright V JS et.al

For environmental, air pollution is one of the main issues faced by the community. Open mining involves substantial clearing and land removal. Air quality degradation mostly related to the pollution of dust due to the processes of mining such as excavation, top soil and vegetation removing,, bauxite and unwanted elements transportation and bauxite stockpiling.

Furthermore, water pollution sources mainly related to extensive land clearing, bauxite extraction leads to soil erosion and sedimentation, bauxite washing and effluent from the bauxite washing pond which flows into the nearby river, and bauxite stockpile in a large quantities without proper drainage system. Other than river and sea pollution, uncontrolled mining activities also cause severe mud flood. This is due to the erosion of soil and surface runoff of cleared land (Noor Hisham et al., 2016).

An ecosystem important elements is soil as it provides nutrients for the plants and also the major site degradation and transference of biomass (Lee KY et al. 2017). Bauxite-contaminated soil can cause harm to the health as its contents can contaminate soil and water sources used in agriculture. The major pathway for human exposure to heavy metal are food products as compared with soil particles inhalation, contact of skin and drinking water (Zhou H et al., 2016). Heavy metal in soil are absorbed which raises issue of food safety among consumers (Wright V JS & Omoruyi FO, 2012). Moreover, habitat destructive reduces the diversity of flora and fauna which is vital for identity of Malaysia as a tropical forest country.

For health impacts, the hazard particles produced from bauxite mining activities cause eyes, nose and throat irritation. These particles deposit on vegetation making it unpalatable for human and livestock consumption (Abdullah N et al., 2016). According to the results from WHO project "systematic review of health aspects of air pollution in Europe" said that PM10 and PM2.5 fine bauxite particles penetrate deep into respiratory system and have been associated with increased hospital diseases as well as premature deaths.

2.3 Kenaf

Hibiscus Cannabinus L. (Kenaf) is a valuable fiber and medicinal plant from the Malvaceae family (Ayadi. R.et.al.,2017). It is an alternative crop that may be a feasible source of cellulose which is economically viable and ecologically friendly. Although the leaves and seeds have also been used in traditional medicine in India and Africa for treatment of various disease conditions but it also cultivated for its fiber. Kenaf fibers are commonly used for paper pulp and the kenaf seed oil can be used for cooking and in different industrial applications. Recently, the total production of kenaf that belongs to China, Thailand and India was up to 95 percent (Tahery et.al.,2011). In early 1970s, it was first presented in Malaysia and was highlighted in 1990s as the substitute and inexpensive important basis of material for manufacturing panel products such as fiberboard, textiles, particleboard and as a also as a source of fuel (Abdul Khalil et. At., 2010).

For over six millennia kenaf has been used as a fiber crop to produce twine, rope and sackcloth (Dempsey, 1975). In northern Africa kenaf was first domesticated and used. India on the other hand has produced and used kenaf for the last 200 years. Besides that, Russia has been producing kenaf since 1902 and introduced the crop to China in 1935. During World War 2, kenaf research and production had already began. It is to supply cordage material for the war effort. The war had interrupted the foreign supply of fiber from Philippines but the US involvement in the war also increased the use of fibers by US. Initially, kenaf was determined as a suitable crop for USA production, a research was conduct to maximized US kenaf. After that, scientists successfully developed high yielding anthracnose-resistant cultivars, cultural practices and harvesting machinery that increased fiber yield. USA researchers were evaluating various plant species to fulfill future fiber demands in the US in the 1950s and early 1960s. It was determined that kenaf was an excellent cellulose fiber source for a large range of paper product, for example newsprint, bond paper and corrugated liner board. The research also proven that the pulping kenaf required less energy and chemical inputs for processing than standard wood sources. On the other hand, in the more recent research, it has showed the plant's suitability for use in building materials such as particle boards of various densities, thickness with fire resistance. It also can be made as adsorbents, textiles, livestock feed and fibers in new and recycled plastics (Webber III et al., 2002).

There are many research on planting of kenaf. Kenaf can be planted in the spring once the soil has warmed to 13 degree Celsius and the threat of frost is past, in United States. Kenaf can planted as early as April or May in most part of United States. Standard planting equipment in a wide range of row spacing can enable planting to be accomplished and can be planted on raised beds or on flat ground. Wedge-shaped kenaf seeds are approximately 6 mm long and 4 mm wide with 35,000 to 40,000 seeds/kg. The grain sorghum and kenaf seed are almost similar in size, hence kenaf is often been planted using grain sorghum planting plates in commercial planters. Kenaf seed is usually planted 1.25 to 2.5 cm deep. It will eventually emerge with two to four days after planting. The life cycle of Kenaf is shown in Figure 2.5. This is due to the color of kenaf seed that make it difficult to see the see when testing the planting depth and placement. It is often advantages to test planting depth with seeds that are more easily detected (Webber III et al., 2002).

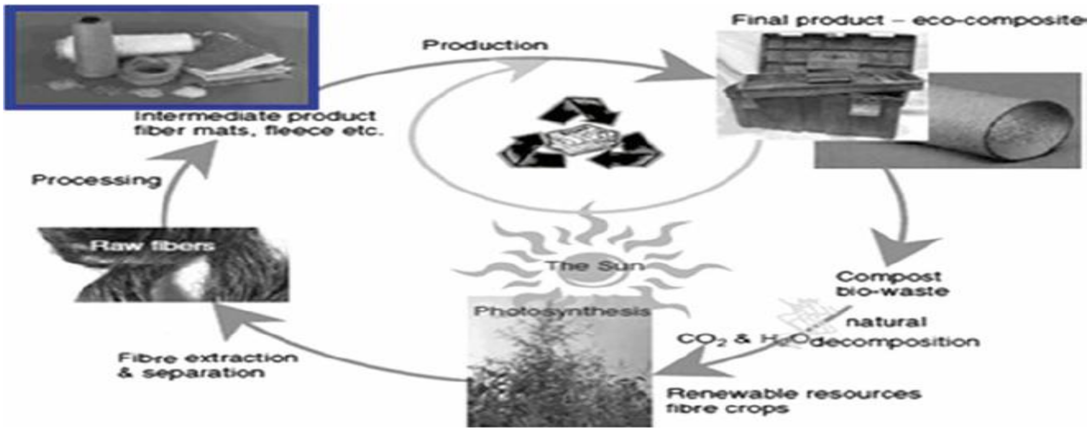

Figure 2.5 Life cycle of Kenaf

Sources: (Webber III et al., 2002)

2.4 Kenaf Fibers

In Polymer Matrix Composites (PMCs) one of the reinforcement is kenaf fibers which one of the natural fibers. Kenaf (*Hibiscus cannabinus, L.* family Malvacea) has been found to be an essential sources of fiber for composite and other industrial application. Besides that, kenaf is famously known as cellulosic source with both ecological and economical advantages. In a short period of 3 months, it is able to grow under a variety range of weather conditions and reach a height of more than 3 m and a base diameter of at least 3-5 cm. This statement is supported by a few studies which claim that growing speed may reach 10cm/day under optimum ambient conditions. The price of kenaf increase from $400 per tonne in 1995 to $278 to $302 per tonne in 2000. In the angle of energy utilization, it takes 15 MJ of energy to produce 1kg of kenaf, however it takes 54 MJ to produce 1kg of glass fiber. The various components of kenaf such as stalks, leaves and seeds has their own value or various usable portions such as fibers, fibers strands, proteins, oils and allelopathic chemicals. All of these yield and components can be affected by various factors including cultivar, planting data, photosensitivity, length of growing season, plant populations and plant maturity. Kenaf filaments consist of discrete individual fibers of generally 2-6mm. The individual fibers properties and filaments can be different depending on sources, age, separating technique and history of fibers. The steam can be separate into bark and core easily either or by chemical or by enzymatic retting. The bark is a rather dense structure which constitutes 30-40% of the steam dry weight. Besides that, the core is wood-like which makes up the remaining 60-70% of the stem. The core also shows an isotropic and almost amorphous pattern, but the bark shows an orientated high crystalline fiber patter (Akil et al., 2011).

Schematic representation of the natural plant cell wall is shown in Fig 6. The structure shown is called microfibril, micro- fiber or the elementary fiber. Generally, all the natural fibers including kenaf fibers, contain 60-80% cellulose, 5-20% lignin and up to 20% moisture. There is a hollow tube with four different layers included in the cell wall, one is primary cell wall, three secondary cell walls and a lumen which is an open channel in the center of microfibril. Each layer is composed of cellulose which embedded in a matrix of hemicellulose and lignin, a structure that is analogous of artificial fiber reinforced composites as shown in Figure 2.6. On the other hand, hemicellulose is made up of highly branched polysaccharides including glucose, mannose, galactose, xylose and others. Lignin is made up of aliphatic and aromatic hydrocarbon polymers positioned around fibers. All the structure and contents of the cell wall differs widely according to various of species and various parts of the plants. The overall properties of kenaf fiber rely on the individual properties of each of its components according to scientists. Cellulose components via hydrogen bonds and other linkages is the main reason for the strength and stiffness of fibers. For hemicellulose, it has the function of biodegradation, moisture absorption and thermal degradation of the fibers. However, lignin is thermally stable but is responsible for the UV degradation of fibers (Akil et al., 2011).

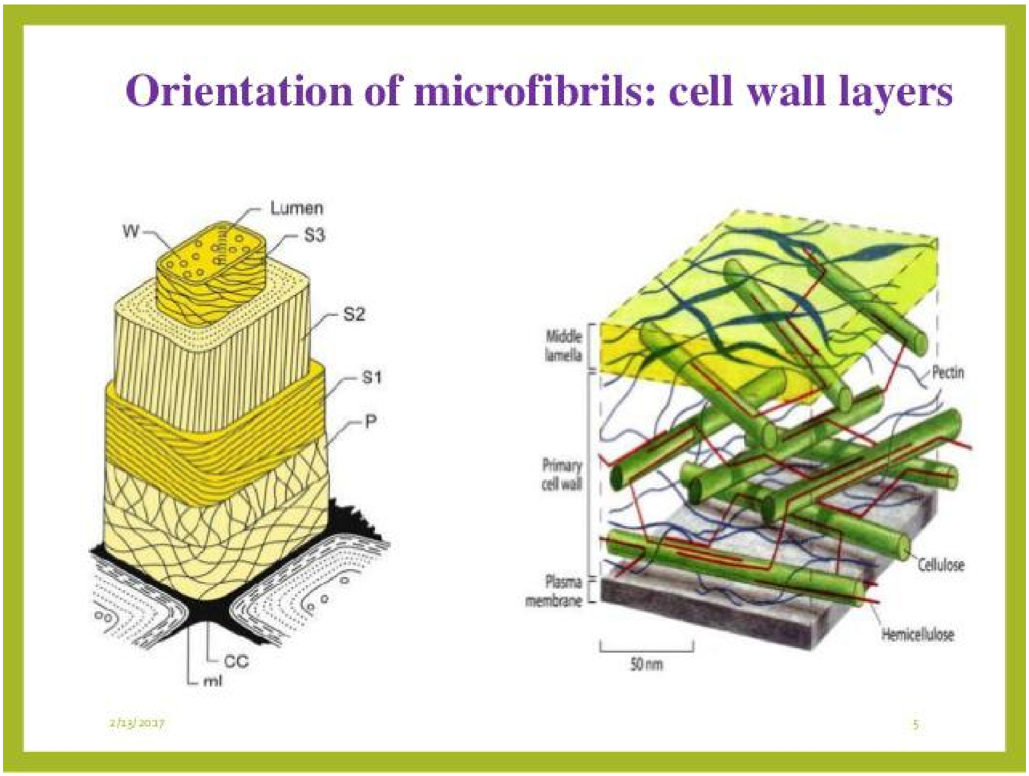

Figure 2.6 Orientation of Microfibrils

2.5 Properties of Kenaf Fiber Reinforced Composities

As most of the other natural fibers, kenaf demonstrates low density, high specific properties of mechanical and it can be easily recycled (Mohanty, A. et al., 2000). Kenaf bast fiber have superior strength of flexural combined with its great strength of tensile that makes it the material of choice for a wide range of extruded, molded and non-woven products (Aji, I.,2009). The properties and structure of natural fibers depends on their age, source, harvest quality, position,the plant body from which the fiber is extracted, the techniques of extraction as well as the site conditions. It also depends on the experimental conditions such as gauge length, strain rate, fiber diameter and test temperature. The physical properties of kenaf fiber were shown in Table 2.3.

Table 2.3 Physical properties of kenaf fiber

Density, g/cm	Tensile strength, MPa	Tensile modulus, MPa	Max. Strain, %
1.45	930	53	1.6
1.4	284-800	21-60	1.6
-	930	53	1.6
-	41.4-214.0	6.8-15.3	0.47-1.39
0.749	223-624	11-14.5	2.7-5.7
-	295-1191	2.86	3.5
-	692	10.94	4.3
1.5	350-600	40	2.5-3.5
0.75	400-550	-	-
0.627	35.43-155.80	2824.44-11463.40	-
1.2	295	-	3-10
0.6	-	-	-
1.2	780	40.738	1.9

Source: Babatunde et al. (2015).

Furthermore, kenaf plant collects heavy metal from the earthy soil ans it has the ability in absorption of CO_2 from atmosphere (Eshet, 2014) as shown in Figure 2.7. Kenaf has been cultivated widely due to its ability to captivate nitrogen and phosphorus that present in the soil and carbon dioxide can be accumulated at a significant high rate (N. Saba et al., 2015). Table 2.4 shows the chemical composition of different fractions of kenaf fiber.

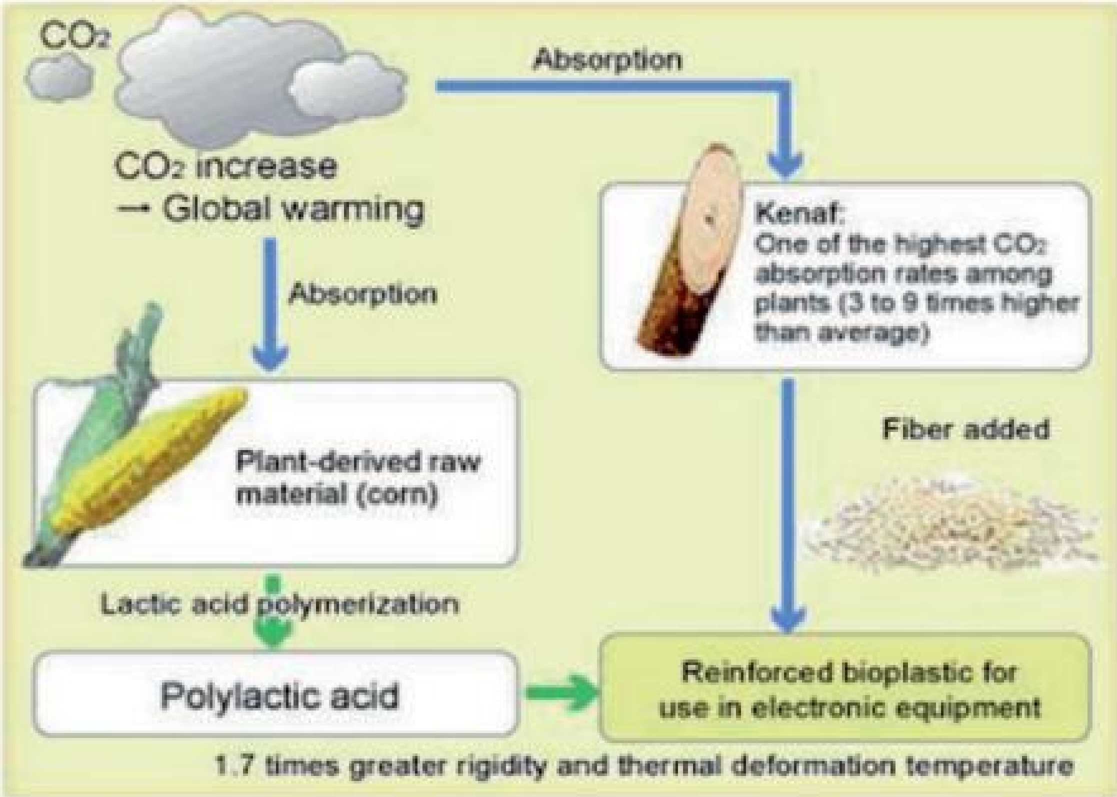

Figure 2.7 Ability of kenaf fiber in absorption of CO_2

Source: N. Saba et al. (2015).

Table 2.4 Different fractions chemical composition of kenaf fiber.

	Kenaf core	Kenaf bast
Extractive (%)	4.7	5.5
Holocellulose (%)	87.2	86.8
Hemicellulose (%)	49	55
Lignin (%)	19.2	14.7
Ash (%)	1.9	5.4

Source:Abdul Khalil et al. (2010)

Kenaf is a very versatile material where it can be utilized for many different usages as shown in Table 2.5. Its leaves contain high digestible protein which can be consumed by animal and human. It was revealed that the average protein content in kenaf leaves range between 18 to 30% where its consumed raw or boiled to greens (Thompson R., 2011).

Mechanical characteristics is where the performance of the materials shine. Example of mechanical characteristics are tensile properties, flexural properties, compression properties, impact properties and wear behavior. It is crucial to determine material ability, especially under crucial and critical conditions, which are directly connected with engineering performance. Plenty of studies have been performed on kenaf fiber composite for the past few years, in order to fully characterize its mechanical behavior. A few of the mechanical properties of kenaf fiber reinforced composites are determined. It included Ultimate tensile strength which is the maximum engineering stress in the tension that may be sustained without fracture or often known as tensile strength. Additionally, there are fracture strain which is the stress fracture from a bend or flexure test, flexural modulus which an indication of a material's stiffness when flexed which is the ratio within the elastic limit of the applied stress on a test specimen in flexure, to the corresponding strain in the outermost fibers of the specimen and lastly the impact strength which the degree of resistance of any material to impact loading with or without a notch in it. Normally, the tensile and flexural properties of kenaf reinforced composite are different depending on the type of fibers, its orientation either is random or unidirectional, content and form and type of blending or plasticizer used. According to statistics shown, the tensile and flexural strength of kenaf reinforced composities were roughly 223 MPa and 254 MPa respectively in samples with a fiber fraction of 70%. Based on the results obtained by this researcher, this verified that kenaf fiber exhibits higher strength values in terms of tensile and flexural properties as compared to other natural fibers when reinforcing PLA. There some research on the fiber content on mechanical properties of kenaf fiber reinforced composite was carried out by scientist. Generally, the results show that optimum tensile properties and Young's modulus are dictated by the volume of reinforcing fiber used for the composites. A can be seen in Figure 2.8, both properties increased with the increase of fiber content and showed the maximum values (Young's modulus; 6.4 GPa, and the tensile strength; 60 MPa) around a fiber content of 70 vol.%. With the fiber content above 70 vol. %, there is a decrease in the mechanical properties of the composite. This could be due to insufficient filling of the matrix resin.

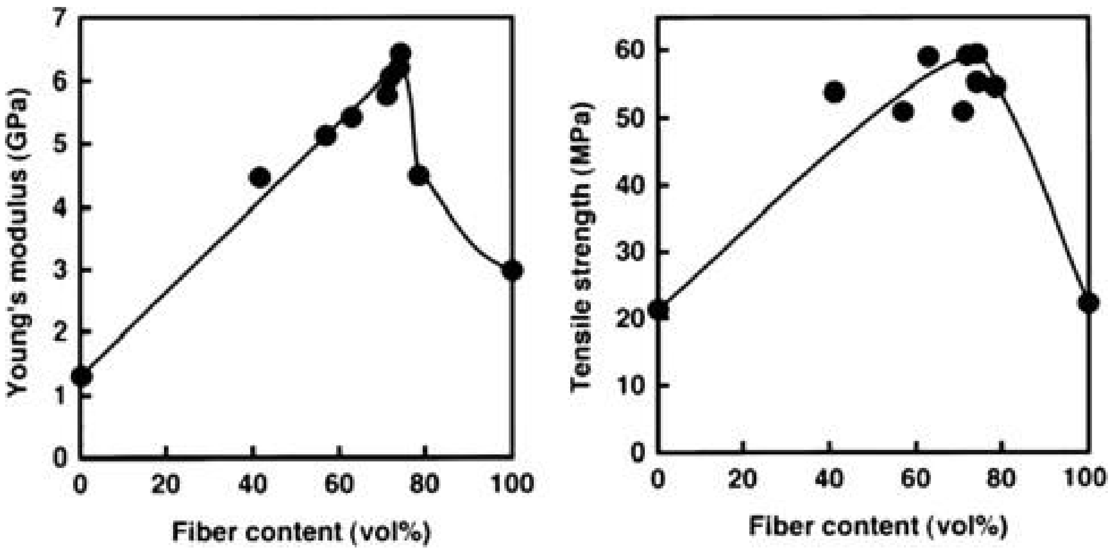

Figure 2.8 Relationship between Young's modulus, the tensile strength, and the kenaf fiber content of kenaf/PLLA composite

Source : Akil et al., 2011

The research reveal that the incorporation of kenaf fibers into the matrix is quite effective for reinforcement. Composite is enhanced in term of mechanical properties compared to those of the kenaf sheet itself. When the sheet was stretched using the tensile tester, there is angular change of the kenaf fiber to the stretching direction was considered to be main deformation mechanism for the sheet. Due to the matrix resin was impregnated into the interfibrillar regions, this type of deformation will be restricted for the composite. This is acknowledged as one of the reason for the reinforcement. Besides that, good stress transfer from the matrix to the incorporated kenaf fibers also another reason (Akil et al., 2011).

2.6 Wind Speed

Wind resources are increasingly being investigated as a clean alternative for generating 4 energies. This paper analyses the daily wind speed recorded at 46 automatic weather 5 stations located in Navarre, northern Spain, in 2005-2015. Key points are the surface 6 density of stations and the range of time that ensure a faithful depiction of wind speed 7 together with surface calculations from image analysis and correlation with height. 8 Different statistics were used. Median wind speed at 10 m was low, about 3.3 m s-1 and 9 its interquartile range was narrow, about 2.3 m s-1. Nearly half the surface shows a 10 median wind speed above 3.0 m s-1. The method of moments was employed to calculate 11 the parameters of the Weibull distribution.

Around half of the surface presented a shape 12 parameter above 2.25 and the scale parameter was above 4 m s-1 for nearly 41% of the 13 region. Although wind resources are not suitable for wind turbine applications in most 14 of the region, since the wind speed is low in low-lying areas, about 12% of the region is 15 suitable for stand-alone applications and, moreover, a substantial part of the region, 16 around 23%, presents satisfactory wind resources for the installation of wind turbines (He *et al*., 2017).

The anemometer height, the exposure of the anemometer as regards the surrounding buildings, hills and trees can affect wind speed data. Besides that, the human factor in reading the wind speed and the quality and maintenance of the anemometer can also affect the wind speed data. All these standardizations of these factors has not been well enforced over some years. For instance, the standard anemometer height is 10m but other heights are often found. In a research, 6 Kansas station in United State with data available from 1948 to 1976 had 21 different anemometer height but none of them was 10m. The only station which did not change anemometer height during this period was Russell, at a 9 m height. Heights ranged from 6 m to 22 m. The anemometer height at Topeka changed five times, with heights of 17.7, 22.3, 17.7, 22.0, and 7.6 m. All the research is happened on United State (He *et al*., 2017).

All the recorded wind data need to be viewed with some caution. Only when anemometer heights and surrounding obstructions are the same can two sites be fairly compared for wind power potential. The recorded data can be used. It is to give an indication of the best regions of the country with local site surveys being desirable to determine the quality of a potential wind power site (He *et al.*, 2017).

2.6.1 World Distribution of Wind

It has been recognized that some areas of the earth's surface have higher wind speeds than others. The picture of ideal terrestrial pressure and wind systems is shown in Figure 2.9. The actual pattern differs strongly from this idealized picture. All these variations are due to mainly to the irregular heating of the earth's surface in both location and time as shown in Figure 8 (Johnson *et al*., 2001).

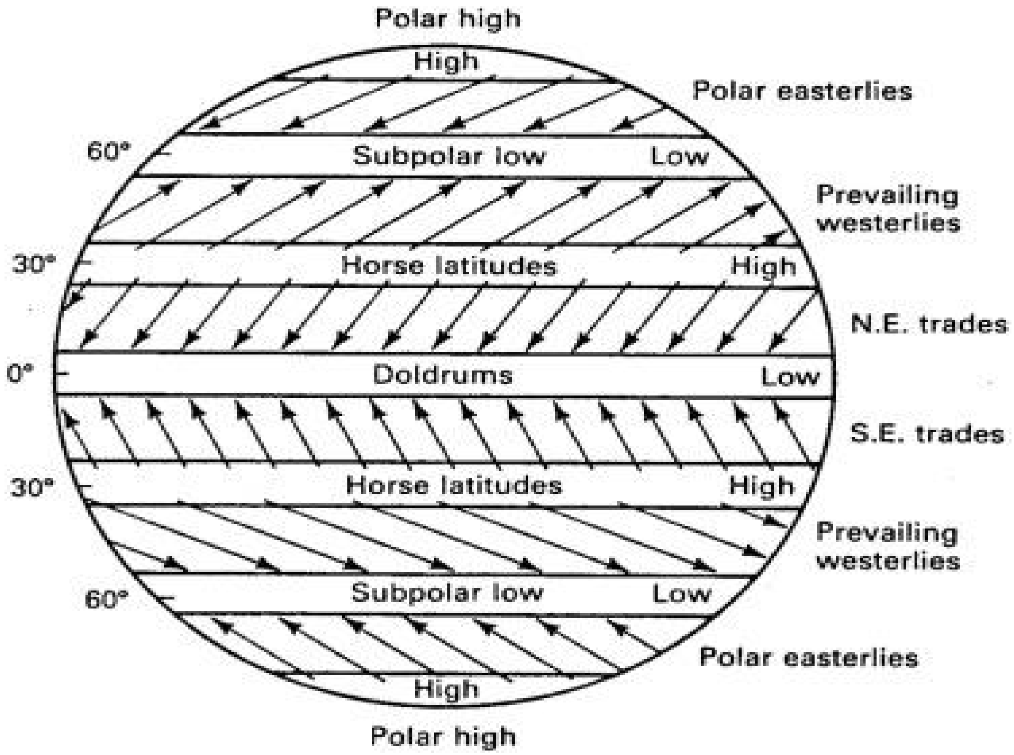

Figure 2.9: Ideal terrestrial pressure and wind systems
Sources: (Johnson et al., 2001)

Due to a belt of low pressure the equatorial calms or doldrums surrounds the earth in the equatorial zone as a result of the average overheating of the earth in this region. There is a strong convection when the warm at here rises. At the time of highest daily temperature, late afternoon showers are common from the resulting adiabatic cooling which is most pronounced. The humidity will be very high without providing much surface cooling by these showers. The atmosphere tends to be oppressive, hot and sticky with the calm winds and slick glassy seas. Region near the equator will not be very good for wind power applications, unless prominent land features change the weather patterns (Johnson *et al*., 2001).

There are two belts of high pressure and relatively light winds which occur symmetrically around the equator at 30° N and 30° S latitude. These are known as the subtropical calms or subtropical highs or horse latitudes. Name is apparently dates back to the sailing vessel days when horses were thrown overboard from becalmed ships to lighten the load and conserve water. The high pressure is kept and hold by vertically descending air inside the pattern. When the air is warmed adiabatically and therefore develops a low relative humidity with clear skies. The bulk of the world's great desert is caused by the dryness of this descending air which lie in the horse latitudes (Johnson *et al*., 2001).

On the other hand, there are two more belts with low pressure which occur at perhaps 60° S latitude and 60° N latitude, the subpolar lows. The low is fairly stable and does not change much from summer to winter is call the Southern Hemisphere. It is due to the global encirclement by the southern oceans at these latitudes. For the Northern Hemisphere, however, there are large land masses and strong temperature differences between land and water. There is also responsible for the lows to reverse and become highs over land in the winter. Additionally, the lows over the oceans called the Iceland low and the Aleutian Low, become especially intense and stormy low pressure areas over the relatively warm North Atlantic and North Pacific Oceans (Herrero-Novoa *et al.*, 2017).

Lastly, the polar regions tend to be high pressure areas more than low pressure. However, the locations and intensities of these highs may be different, with the center of high only rarely located at the geographic pole (Johnson *et al*., 2001).

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter discussed the methodology of this research in order to achieve the objectives of this research which were to study the reduction of air pollutants concentration by using different thickness of *Hibiscus Cannabinus L.* (Kenaf) and the influence of wind speed and to propose the safe environment index for different thickness of *Hibiscus Cannabinus L.*(Kenaf) in air pollutants reduction. The research flow chart was shown in Figure 3.1 and the three main stages of the research flow chart discussed in section 3.1 in this chapter were research stage, experimental stage and discussion stage. Firstly, in research stage were running project research, novelty of the research as well as the study of feasibility. Preparation of materials and equipment of experiment were conducted in experimental stage. Last but no least, collecting results or data, discussion and conclusion were drawn in the discussion stage.

The materials and equipment used in experiment were described in section 3.2. For section 3.3 was about research analytical method and experiment procedure was described in section 3.4. The last section in this chapter was discussed the research statistical analysis.

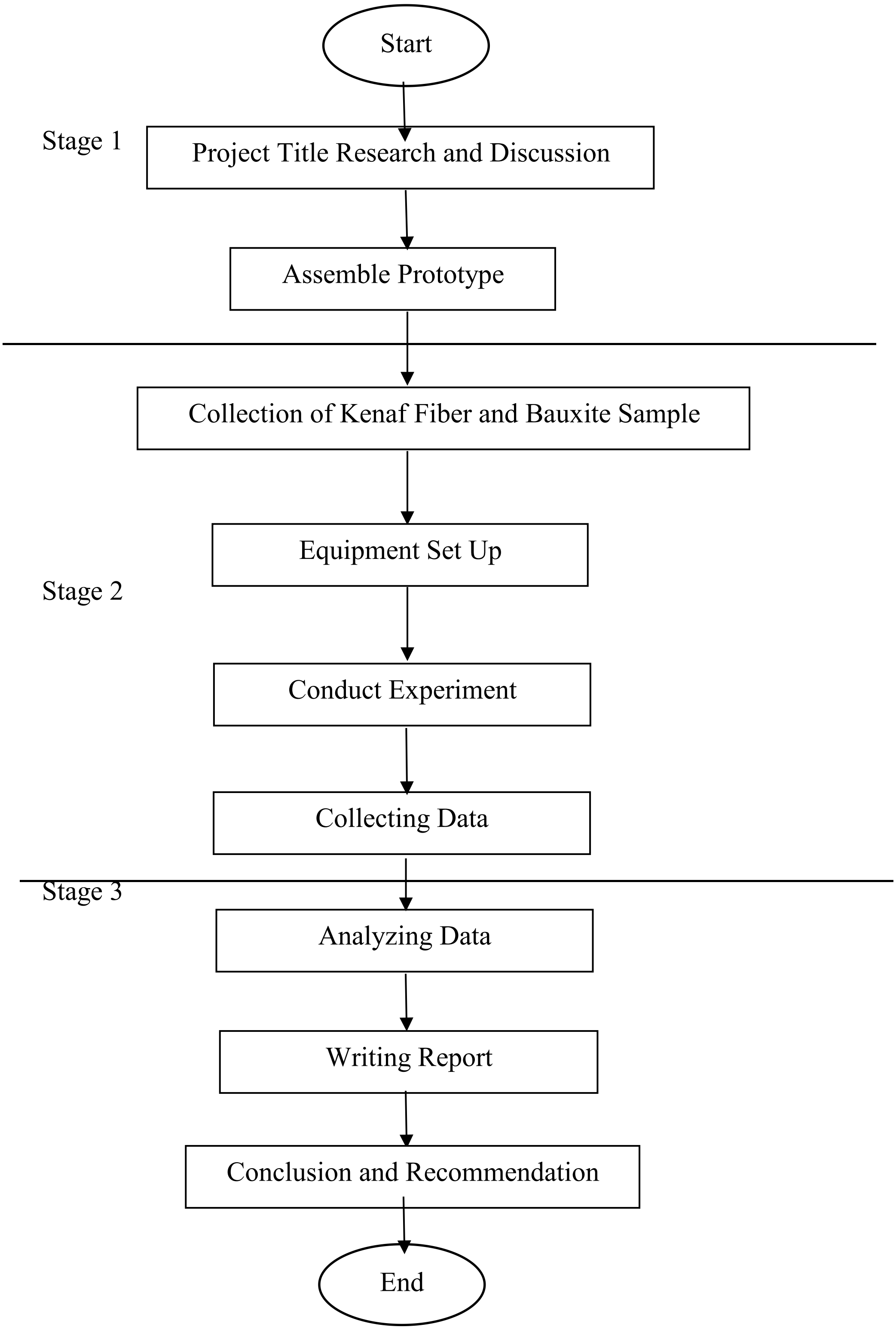

Figure 3.1 Research Flow Chart

3.2 Materials and Equipment

In this research, materials used for testing and fabricated prototype and two main equipment were set-up to run the experiment. The details were discussed as follow:

3.2.1 Bauxite Sample

The sample of bauxite was collected from Felda Bukit Goh, Kuantan as the source of air pollutants. It taken from the stockpile of bauxite that was gathered in the port before it to undergo other processes. The bauxite bought back was heated in the oven to remove the moisture content in the sample so the sample displayed well while conducting the experiment.

3.2.2 Kenaf Fiber

Kenaf fiber played an important character in this research which act as air filtration system. The Kenaf fiber used in this research was collected from the factory in Kuala Terengganu. The thickness of Kenaf fiber is one of the manipulated variable in the experiment.

3.2.3 Direct Sense Monitoring Kit and Dust Detective / Portable Air Sampler

Direct sense monitoring kit or gas detector is one of the equipment used in the experiment to detect the harmful gases released from the sample collected such as Ammonia (NH_3), Nitrogen Dioxide (NO_2), Hydrogen Sulfide (H_2S), Sulfur Dioxide (SO_2) and Chlorine (Cl_2) whereas the particular matter (PM_{10}) that present in the prototype was detected by using dust detector. This two equipment are available in the Environment Laboratory UMP.

Figure 3.2 Dust Detective / Portable Air Sampler

3.2.4 Assemble Prototype

In this research a prototype is designed to conduct experiment. Acrylic board was used to build a 1000*500*500mm transparent compartment to run the test as shown in Figure 3.3. Acrylic board was chosen as the design material was due to it transparency for observation purpose and it ability to cut and join for design purpose.

The experiment was conducted with two manipulated variables which were thickness of kenaf fiber and the wind speed. The experiment was ran in a closed room to ensure surrounding temperature was constant.

3.3 Analytical Method

This section was discuss the harmful gases or air pollutants that present from the bauxite sample which cause the air pollution issues. The dust detector was used to detect the dust particular matter (PM_{10}) and the harmful gases such as Ammonia (NH_3), Nitrogen Dioxide (NO_2), Hydrogen Sulfide (H_2S), Sulfur Dioxide (SO_2) and Chlorine (Cl_2) were detected by gas detector. From the overall parameters, PM_{10}, NO_2 and SO_2 were involved in the Air Pollution Index (API) System. The detectors will showing the concentration of the parameters present in the air.

3.4 Experiment Procedure

Firstly, the bauxite sample was heated until all the moisture content in the bauxite sample was eliminated. Next, the dried bauxite sample was placed in the bottom of the prototype. Kenaf fiber was not applied in the control experiment but wind was applied into the system as shown in Figure 3.3. The data of the substances concentration were collected and recorded. The procedure was repeated by applying the kenaf fiber layer by layer on top of the bauxite sample and the bauxite sample was fully covered as shown in Figure 3.4. All data shown from both detectors was then recorded for analysis and discussion purposes. Tables and graphs were obtained to understand the relationships between the parameters and the changes.

Figure 3.3 Setting up equipment for testing without kenaf fiber

Figure 3.4 Experiment for testing with kenaf fiber

Figure 3.5 Recording data

3.5 Statistical Analysis

In this research, data or results were recorded for analyzation purpose. The concentration of the harmful gases and PM_{10} were recorded in the condition of various thickness of kenaf fiber and wind speed with constant temperature. Data recorded was tabulated and graphs were distributed to do analysis, discussion and also to conclude the relationship between the variables.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter discussed the results collected through the experiment conducted where thickness of kenaf fiber and wind speed were the influence factors in this research. The discussion of difference thickness of kenaf fiber on air pollutant reduction will be in section 4.2 whereas 4.3 discussed the influence of wind speed towards the experiment. Lastly, the safe environment index for different thickness of *Hibiscus Cannabinus L.*(Kenaf) in air pollutants reduction was proposed in section 4.4 in this chapter.

4.2 Influence of Kenaf Fiber Thickness and Wind Speed on Air Pollutant Reduction

The influence of different thickness of kenaf fiber and wind speed was observed and the results were recorded. Control experiment was conducted in three difference wind speed without kenaf fiber. The data and results were shown as follow:

4.2.1 Particular Matter (PM_{10})

Table 4.1 Average concentration (mg/m^3) of PM_{10}

Variables	**Wind speed 1**	**Wind speed 2**	**Wind speed 3**
Control (C)	0.020	0.024	0.028
One Layer	0.013	0.014	0.021
Two Layers	0.010	0.009	0.014
Three Layers	0.002	0.005	0.012

The average concentration of PM_{10} for data monitoring was taken 24 hours. The temperature was constant since the experiment conducted in indoor. From the result in

Table 4.1, the average concentration of PM_{10} with kenaf fiber was decreased as compared to the control result which was without kenaf fiber. The average concentration reduced as the thickness of kenaf fiber increased.

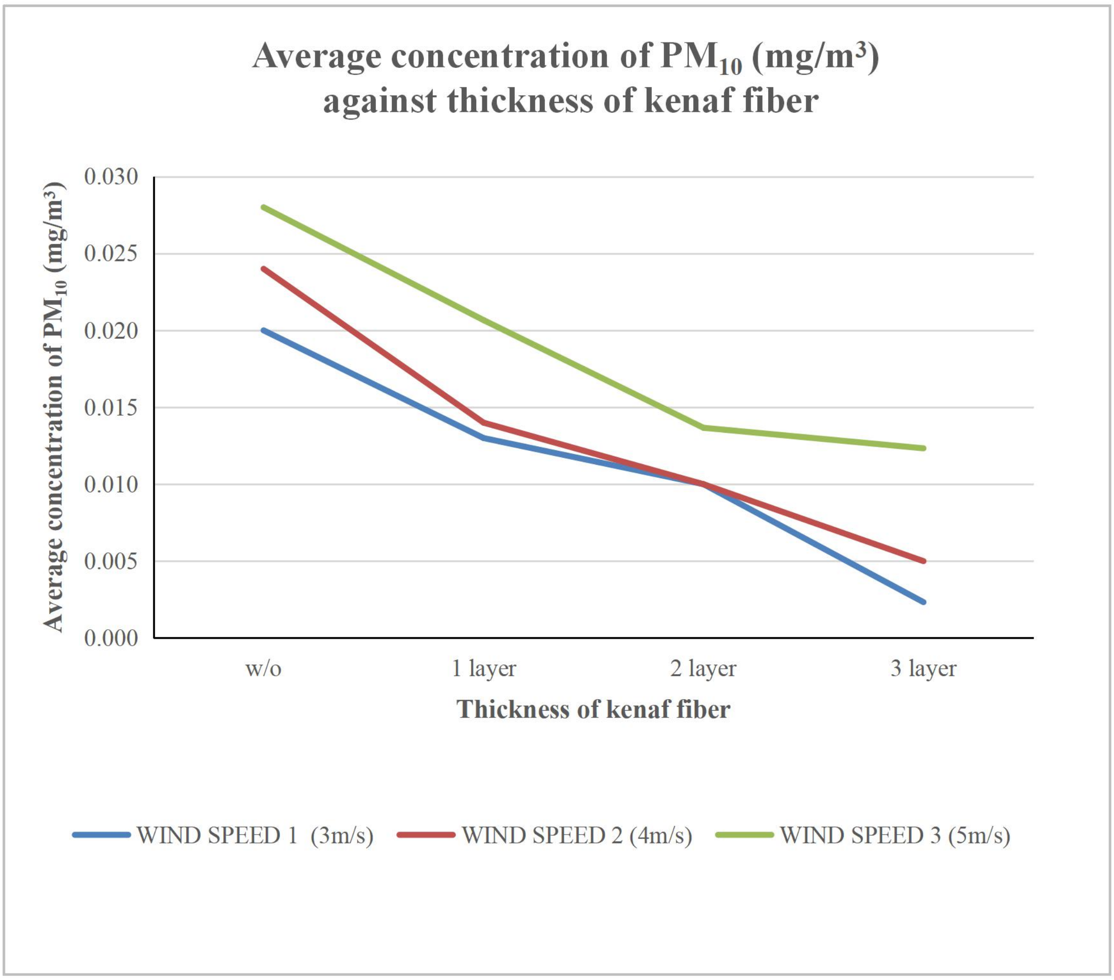

Figure 4.1 Average concentration of PM_{10} against thickness of kenaf fiber

From the Figure 4.1, it was clearly shown that the average concentration of PM10 was reduced as kenaf fiber has the ability to filter the impurities substances in the air. The average concentration of PM_{10} was 0.020 mg/m^3 without apply kenaf fiber in the experiment and it reduced 30% of it concentration when one layer of kenaf fiber was applied. The average concentration of the substance reduced when one layer, two layers and three layers of kenaf fiber was applied which the concentration were 0.013mg/m^3, 0.010mg/m^3 and 0.002mg/m^3 respectively in wind speed level 1.

The similar trend occurred in wind speed level 2 and wind speed level 3 where the average concentration of PM_{10} was reduced from 0.024mg/m^3 to 0.014mg/m^3, 0.010mg/m^3 and 0.005mg/m^3 in wind speed level 2 whereas in wind speed level 3 were reduce from 0.028mg/m^3 to 0.021mg/m^3, 0.014mg/m^3 and 0.012mg/m^3 for one, two and three layers of kenaf fiber applied. The figure shown as the wind speed increased, the average concentration of the substance also increased.

4.2.2 Chlorine (Cl_2)

Table 4.2 Average concentration (ppm) of Chlorine (Cl_2)

Variables	Wind speed 1	Wind speed 2	Wind speed 3
Control (C)	0.017	0.037	0.049
One Layer	0.004	0.013	0.021
Two Layers	0.000	0.001	0.006
Three Layers	0.000	0.000	0.002

The average concentration of Cl_2 for data monitoring was taken in an average for 3 hours. The temperature was constant since the experiment conducted in indoor. From the result in Table 4.2, the average concentration of Cl_2 with kenaf fiber was decreased as compared to the control result which was without kenaf fiber. The average concentration reduced as the thickness of kenaf fiber increased.

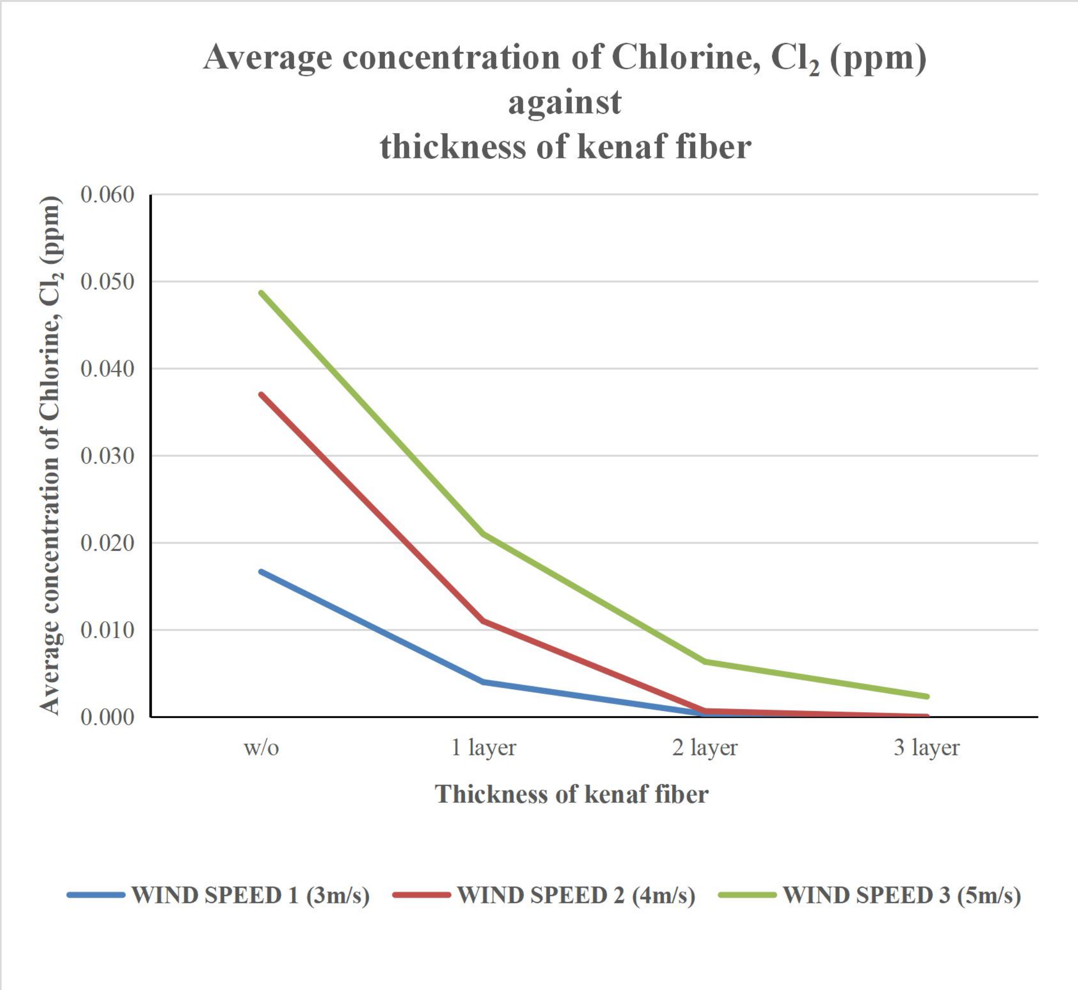

Figure 4.2 Average concentration of Cl_2 against thickness of kenaf fiber

From the Figure 4.2. it was clearly shown that the average concentration of Cl_2 was reduced as kenaf fiber has the ability not only to filter impurities substances in the air but also able to filter the the harmful gases present in the air. The average concentration of Cl_2 was 0.017 ppm without apply kenaf fiber in the experiment and it reduced 76% of it concentration when one layer of kenaf fiber was applied. The average concentration of the gas reduced when one layer, two layers and three layers of kenaf fiber was applied in the experiment which the concentration of the gas were 0.013ppm, 0.010ppm and 0.002ppm respectively in wind speed level 1.

The trend was similar in wind speed level 2 and wind speed level 3 where the average concentration of Cl_2 was reduced from 0.037ppm to 0.013ppm, 0.001ppm and 0ppm in wind speed level 2 whereas in wind speed level 3 were reduce from 0.049ppm to 0.021ppm, 0.006ppm and 0.002ppm for one, two and three layers of kenaf fiber applied. The figure shown as the wind speed increased, the average concentration of the substance also increased.

4.2.3 Nitrogen Dioxide (NO_2)

Table 4.3 Average concentration (ppm) of Nitrogen Dioxide (NO_2)

Variables	Wind speed 1	Wind speed 2	Wind speed 3
Control (C)	0.036	0.052	0.069
One Layer	0.035	0.041	0.058
Two Layers	0.017	0.021	0.034
Three Layers	0.002	0.004	0.011

The concentration of NO_2 for data monitoring was taken in an hour and the result shown in Table 4.3 was the average concentration of 3 hours. The temperature remained constant as the experiment conducted in indoor. From the result in Table 4.3, the average concentration of NO_2 with kenaf fiber was decreased as compared to the control result which was without kenaf fiber. The average concentration reduced as the thickness of kenaf fiber increased.

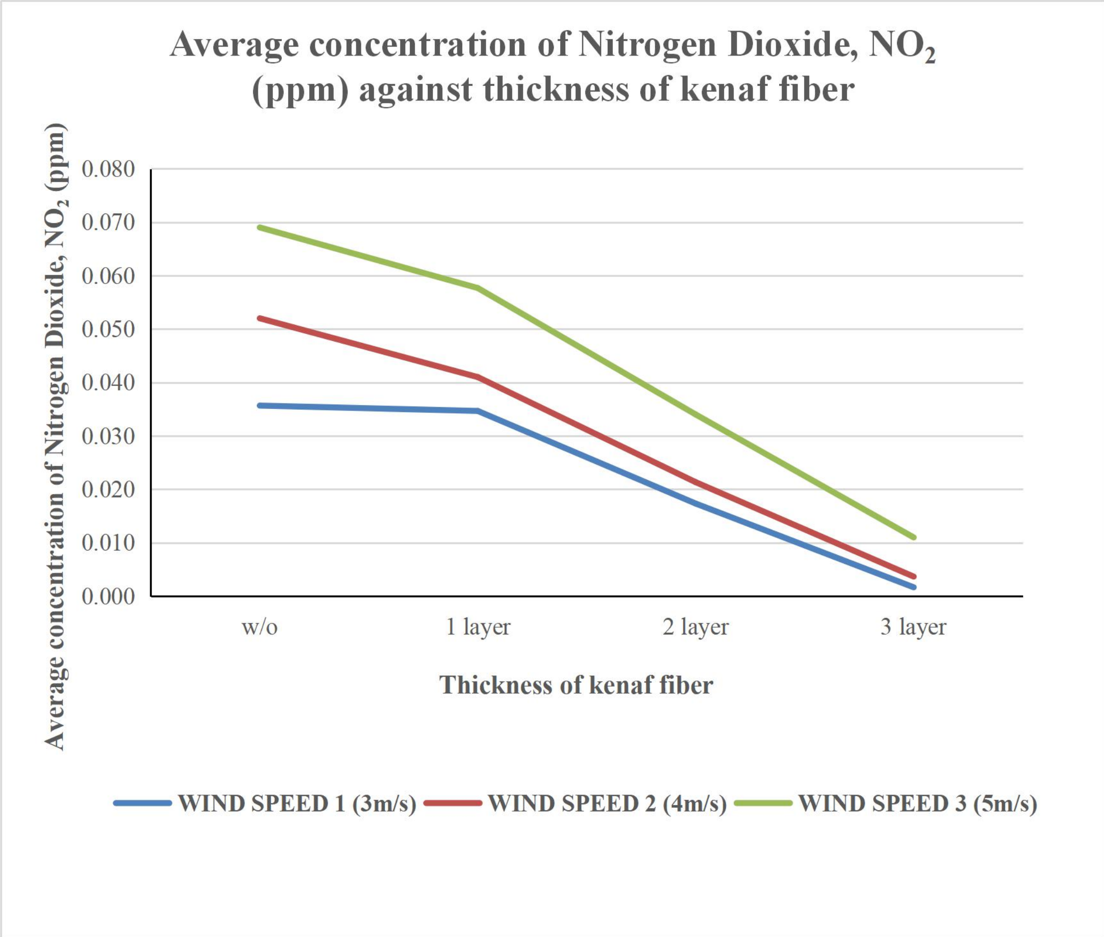

Figure 4.3 Average concentration of NO_2 against thickness of kenaf fiber

From the Figure 4.3. it was clearly shown that the average concentration of NO_2 was reduced as kenaf fiber can filter the harmful gases present in the air. The average concentration of NO_2 was 0.036ppm without apply kenaf fiber in the experiment and it reduced to 0.035ppm when one layer of kenaf fiber was applied. The average concentration of NO_2 reduced when one layer, two layers and three layers of kenaf fiber was applied which the concentration were 0.035ppm, 0.017ppm and 0.002ppm respectively in wind speed level 1.

The similar trend occurred in wind speed level 2 and wind speed level 3 where the average concentration of NO_2 was reduced from 0.052ppm to 0.041ppm, 0.021ppm and 0.004ppm in wind speed level 2 whereas in wind speed level 3 were reduce from 0.069ppm to 0.058ppm, 0.034ppm and 0.011ppm for one, two and three layers of kenaf fiber applied. The figure shown as the wind speed increased, the average concentration of NO_2 also increased.

4.2.4 Ammonia (NH_3)

Table 4.4 Average concentration (ppm) of Ammonia (NH_3)

Variables	Wind speed 1	Wind speed 2	Wind speed 3
Control (C)	0.367	0.600	0.833
One Layer	0.000	0.000	0.000
Two Layers	0.000	0.000	0.000
Three Layers	0.000	0.000	0.000

The average concentration of NH_3 for data monitoring was taken in 3 hours. The temperature was remained constant as the experiment conducted in indoor. From the result in Table 4.4, the average concentration of NH_3 with kenaf fiber was decreased as compared to the control result which was without kenaf fiber. The average concentration reduced as the thickness of kenaf fiber increased.

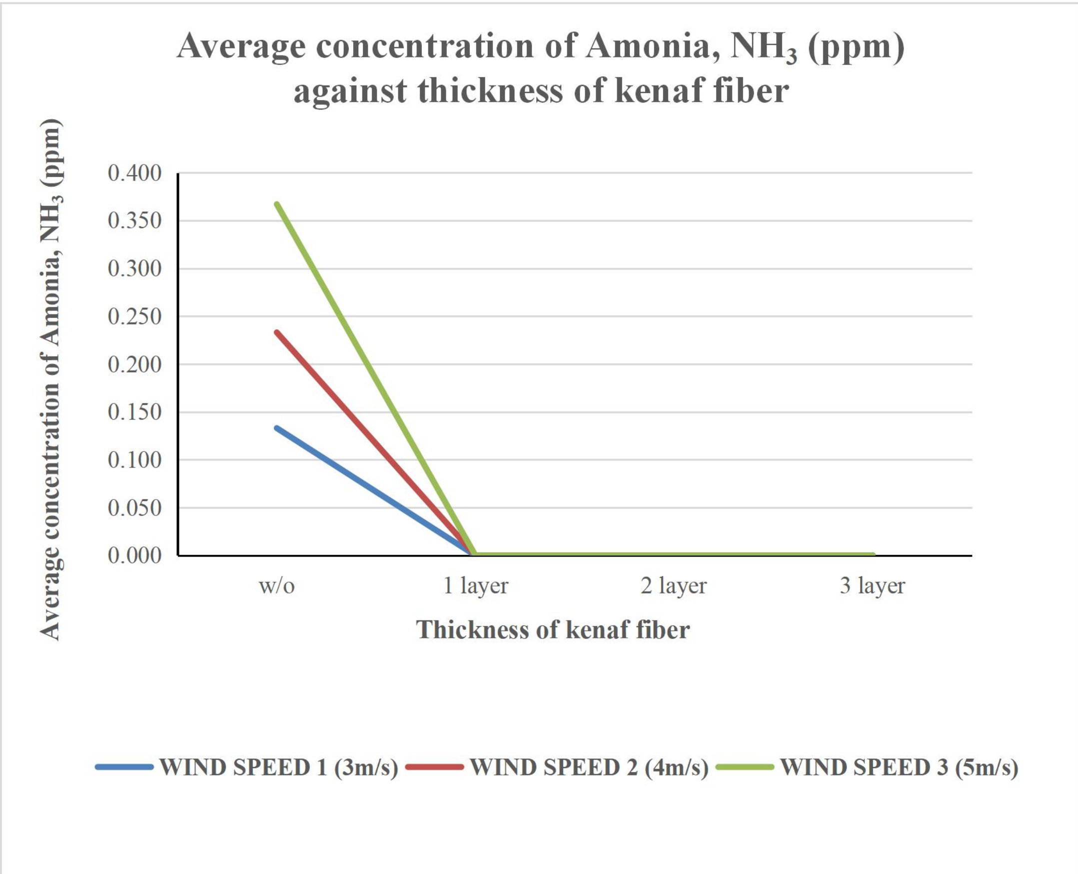

Figure 4.4 Average concentration of NH_3 against thickness of kenaf fiber

From the Figure 4.4. it was clearly shown that the average concentration of NH_3 was reduced as kenaf fiber has the ability to filter NH_3 present in the air. The average concentration of NH_3 was 0.367ppm at wind speed 3 without apply kenaf fiber in the experiment and it reduced 100% of it concentration when one layer of kenaf fiber was applied. The average concentration of the substance reduced when one layer, two layers and three layers of kenaf fiber was applied which the concentration were 0ppm, for all three stages of thickness in wind speed level 1.

The similar trend occurred in wind speed level 2 and wind speed level 3 where the average concentration of NH_3 was reduced from 0.600ppm to 0ppm in wind speed level 2 whereas in wind speed level 3 were reduce from 0.833ppm to 0ppm for one, two and three layers of kenaf fiber applied. The figure shown as the wind speed increased, the average concentration of the substance also increased.

4.2.5 Discussion of Wind Speed

There are many factors that affecting the air pollution level and wind in one of the factor in this research. Horizontal dispersion of air pollutants depends upon the wind speed and the wind direction. Besides that, buildings in cities can also obstruct wind flow thus further aggravating air pollution problems. There were 3 level of wind speed chosen for each of the experiment. For the level 1 wind speed has the speed of 3.0m/s, 4.0m/s for level 2 and wind speed level 3 with the wind speed of 5.0m/s. The 3 level of wind speed is modified based on the data obtained from meteorological department of Pahang. The value obtained was based on 3 years which was year 2015, 2016 and 2017. The average wind speed for the 3 years is 3.0m/s. The average wind speed for this research study was made to be highest at 5.0m/s. The highest wind speed level is also based on the highest level of wind speed recorded on the report given by the meteorological department Pahang.

The concentration of air pollutants increased with increasing of wind speed as the results shown in Figure 4.5 below. This scenario that caused by the wind speed where the particles dispersed into the air by the wind speed. According to a research, with the help of wind speed, the active particle can be easily dispersed into the air (Herrero-Novoa et al., 2017). When the wind speed is able to sustain the weight of the small particle in the bauxite sample, it is able to disperse into the air and causing air pollution.

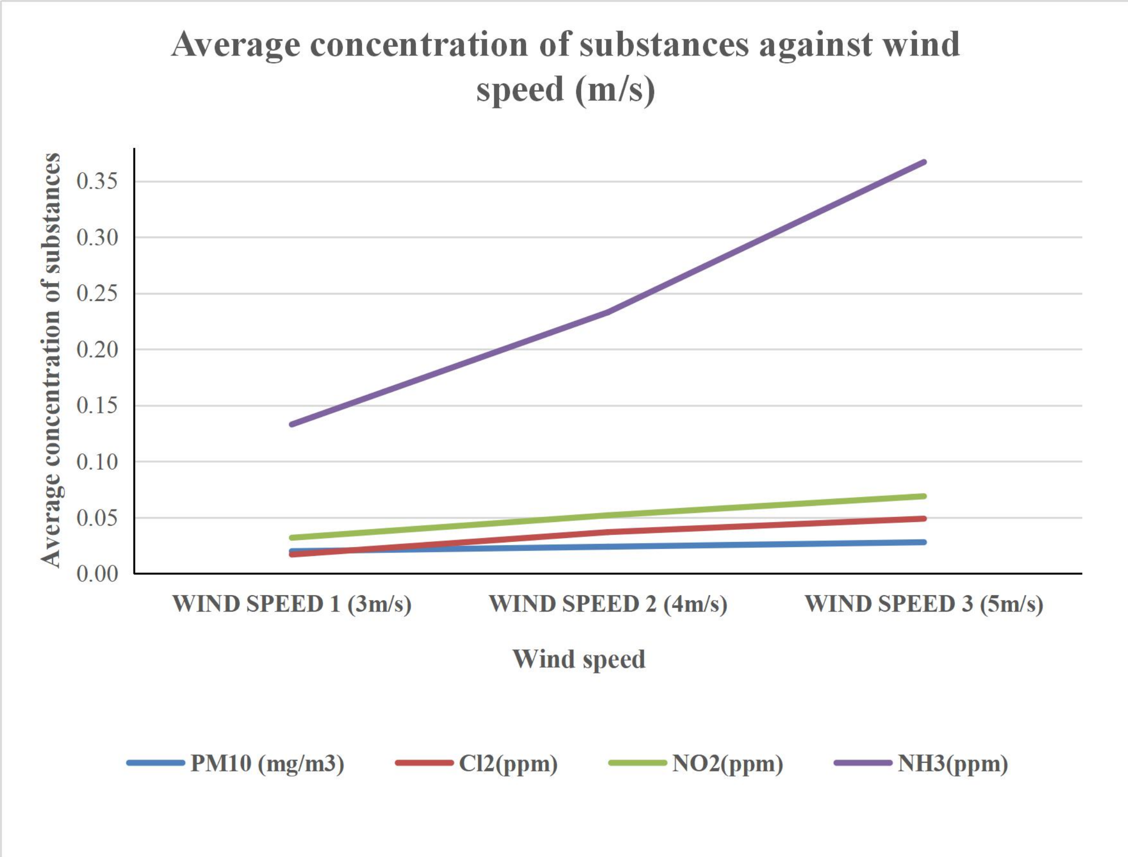

Figure 4.5 Average concentration of substances against wind speed

From the result shown in Figure 4.5, it shown that the concentration of substances was increased as the wind speed increased. At wind speed 1,the concentration of PM_{10} was 0.020mg/m^3 and increased to 0.024mg/m^3 and 0.028mg/m^3 in wind speed level 2 and 3 respectively. Next, the concentration of Cl_2 was 0.017ppm and increased to 0.037ppm and 0.049ppm at wind speed 2 and 3 respectively. Whereas for NO_2, concentration of 0.036ppm, 0.052ppm and 0.069ppm was obtained at wind speed 1, 2 and 3 respectively. Lastly, the concentration of NH_3 was 0.133ppm at wind speed 1 and it increased to 0.233ppm and 0.367ppm at wind speed 2 and 3 respectively.

4.3 Air Pollution Index (API)

Air Pollution Index (API) system is a means for reporting the quality of air or level of air pollution, which developed in easily understood ranges of values instead of using the actual concentrations of air pollutants. In API, the commonly used individual air pollutants are Particular Matter (PM_{10}), Sodium Dioxide (SO_2), Ozone (O_3), Carbon Monoxide (CO), and Nitrogen Dioxide (NO_2). The primary purpose of an API system is to measures the health risk related to short-term exposure to air pollutants, therefore it would be natural for the system to track pollutant concentrations over a shorter averaging time. According to a research, calculation of the API is usually based on 1-hour, 8-hour, or 24-hour average monitoring data, depending on the pollutants (Ove Arup, 2007). Table 4.5 shown the average time for data monitoring and Table 4.6 shown the API values by level of pollutants and health measures.

Table 4.5 Average time of air pollutants for data monitoring

Air Pollutants	**Average Time (hr)**
SO2	24
PM10	24
O3	1
CO	8
NO2	1

Source: Ove Arup (2017).

Table 4.6 Air pollution index and associated health advice

API	**STATUS**	**POLLUTION LEVEL**	**HEALTH MEASURES**
0-50	Good	Low pollution and no ill effect on health	No restriction of activities for all group of people
51-100	Moderate	Moderate pollution and no ill effect on health	No restriction of activities for all group of people
101-200	High	Mid aggravation of symptoms among high risk person (lung and heart diseases)	Restriction of outdoor activities for high risk people. Public should reduce outdoor activities
201-300	Very High	Significant aggravation of symptoms and decreased exercise tolerance in person with lung or heart diseases	High risk people should stay indoor and avoid physical activities. Public should avoid rigorous outdoor activities
301-500	Serious	Severe aggravation and endanger health	High risk people should stay indoor and avoid physical activities. Public should avoid rigorous outdoor activities
>500	Emergency	Severe aggravation and endanger health	Public advised to follow the orders of National Security Council and always follow announcement through mass media

Source: Wong TW (2012).

In this research, the substances that involved in API system were PM_{10} and NO_2, therefore the API was calculated based on the API sub-index function as shown in

Table 4.7. The API value was the maximum value among API sub-index for PM_{10} and NO_2 as shown in Table 4.8.

Table 4.7 API sub-index function

Air Pollutants	**Range of concentration**	**API**
CO	conc.<9 ppm	API=conc. X 11.11111
	9 ppm<conc.<15ppm	API=100+[(conc.-9)x16.6667]
	15ppm<conc.<30ppm	API=200+[(conc.-15)x6.6667]
	conc.>30ppm	API=300+[(conc.-30)x10]
O_3	conc.<0.2 ppm	API=conc. X 1000
	0.2 ppm<conc.<0.4ppm	API=200+[(conc.-0.2)x500]
	conc.>0.4ppm	API=300+[(conc.-0.4)x1000]
NO_2	conc.<0.17 ppm	API=conc. X 588.23529
	0.17 ppm<conc.<0.6ppm	API=100+[(conc.-0.17)x232.56]
	0.6ppm<conc.<1.2ppm	API=200+[(conc.-0.6)x166.667]
	Conc.>1.2ppm	API=300+[(conc.-1.2)x250]
SO_2	conc.<0.04 ppm	API=conc. X 2500
	0.04 ppm<conc.<0.3ppm	API=100+[(conc.-0.04)x384.61]
	0.3ppm<conc.<0.6ppm	API=200+[(conc.-0.3)x333.333]
	conc.>0.6ppm	API=300+[(conc.-0.6)x500]
PM_{10}	conc.<50 μg/m^3	API=conc.
	50μg/m^3<conc.<350μg/m^3	API=50+[conc.-50)X50]
	350μg/m^3<conc.<420μg/m^3	API=200+[(conc.-350)x1.4286]
	420μg/m^3<conc.<500μg/m^3	API=300+[(conc.-420)x1.25]
	conc.>500μg/m^3	API=400+(conc.-500)

Table 4.8 API sub-index and maximum API value for each condition

Condition	**API sub-index for PM_{10}**	**API sub-index for NO_2**	**API**
Control	28	38.52	38.52
One Layer	21	32.38	32.38
Two Layers	14	18.98	18.98
Three Layers	12	6.14	12.00

From the result shown in Table 4.8, the maximum API was obtained from API sub-index of NO_2 which were 38.52, 32.38 and 18.98 for condition without kenaf fiber, one layer of kenaf fiber and two layers of kenaf fiber respectively. For three layers of kenaf fiber, the maximum API was obtained from API sub-index of PM_{10} which was 12.00.

Kenaf fiber is observed to perform better in reduction of air pollutants in gas phase compared to solid phase which might because of hemicelluloses in Kenaf fiber are responsible for moisture absorption (Ramesh, 2016).

4.4 Safe Environment Index

The graphs of safe environment index for PM_{10}, Cl_2, NO_2 and NH_3 were obtained in this section. The graphs obtained provide information for kenaf fiber thickness, concentration of air pollutants and the air pollutants reduction efficiency which shown in Figures 4.6.4.7, 4.8 and 4.9 for PM_{10}, Cl_2, NO_2 and NH_3 respectively. This enable researchers to understand the relationship among them which how the thickness of kenaf fiber affected the air pollutants concentration as well as the performance in reducing the air pollutants.

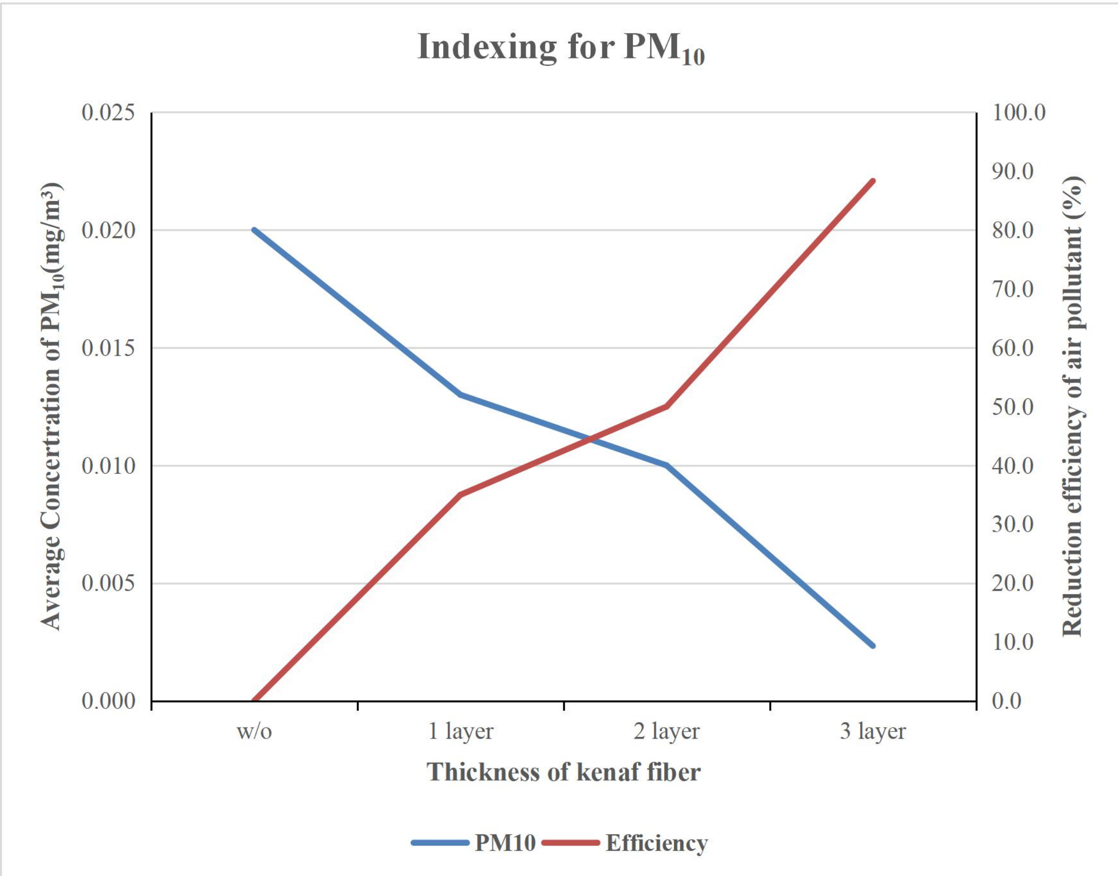

Figure 4.6 Safe environment index of PM_{10}

The figure above shown that kenaf fiber has the ability in reducing the Particular Matter that present in the prototype from bauxite sample. The effectiveness in reducing

PM_{10} was increased continuously as thicker kenaf fiber was applied. The average concentration of PM_{10} was 0.020mg/m^3 when no kenaf fiber was applied and it reduce to 0.002mg/m^3 when 3 layers of kenaf fiber was applied on top of the bauxite sample. The maximum reduction efficiency was 88.3% when 3 layers of kenaf fiber was applied in the system. The efficiency of Kenaf fiber in reducing concentration of PM_{10} was observed lower compared with reducing concentration of gaseous air pollutants such as NH_3, NO_2 and Cl_2. This might be because of the hydroxyl and oxygen containing group inside the cell wall polymers, which preferring to absorb moisture content in the atmosphere through hydrogen bonding (Ramesh, 2016). The PM_{10} will absorbed by the Kenaf fiber when it absorbs the surrounding moisture content but PM_{10} with greater size and diameter might still escape from the absorption. The possible reason for the PM_{10} to escape from the absorption might because of the diameter of fibrous pore was smaller than the diameter of PM_{10} and the atmosphere with far distance with Kenaf fiber which make Kenaf fiber unable to absorb the air pollutants at the upper part of the prototype.

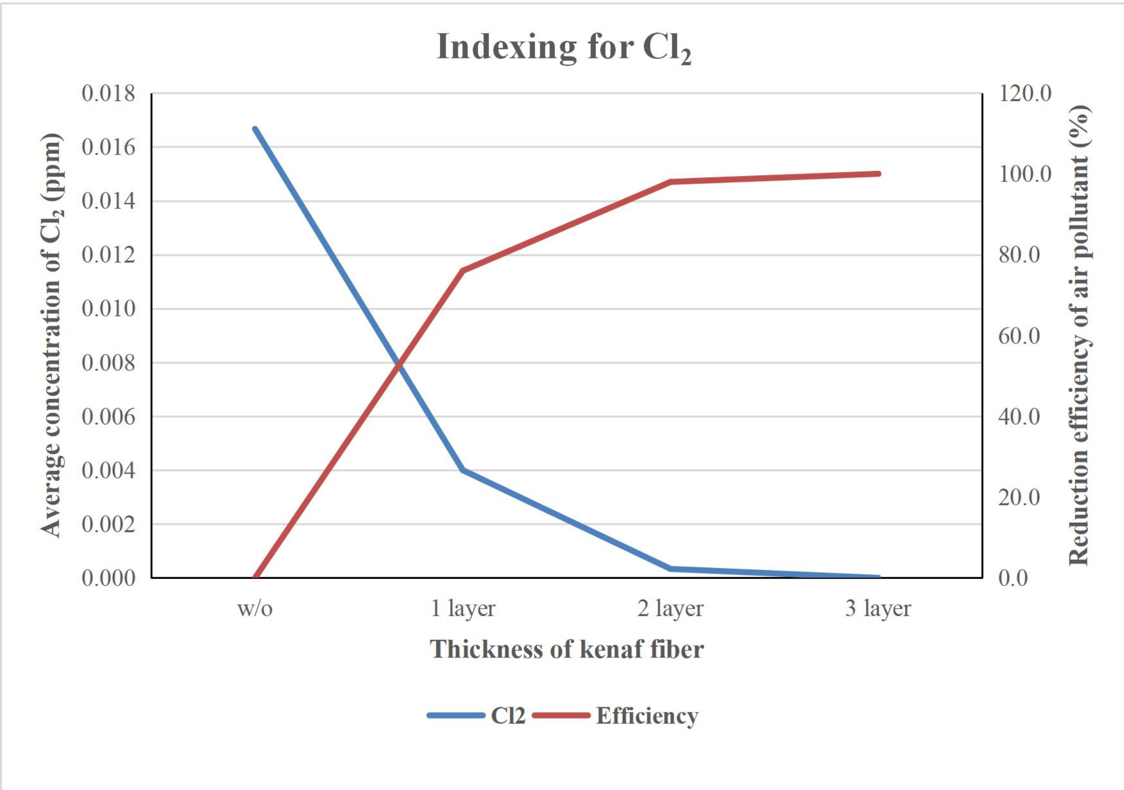

Figure 4.7 Safe environment index of Cl_2

The figure above shown that kenaf fiber has the ability in reducing the gas of Cl_2 that present in the air from the bauxite sample. The effectiveness in reducing Cl_2 was increased continuously as the thickness of kenaf fiber increased. The average concentration of Cl_2 was 0.017ppm when no kenaf fiber was applied and it reduce to 0ppm when 3 layers of kenaf fiber was applied on top of the bauxite sample. The maximum reduction efficiency was 100% when 3 layers of kenaf fiber was applied in the system.

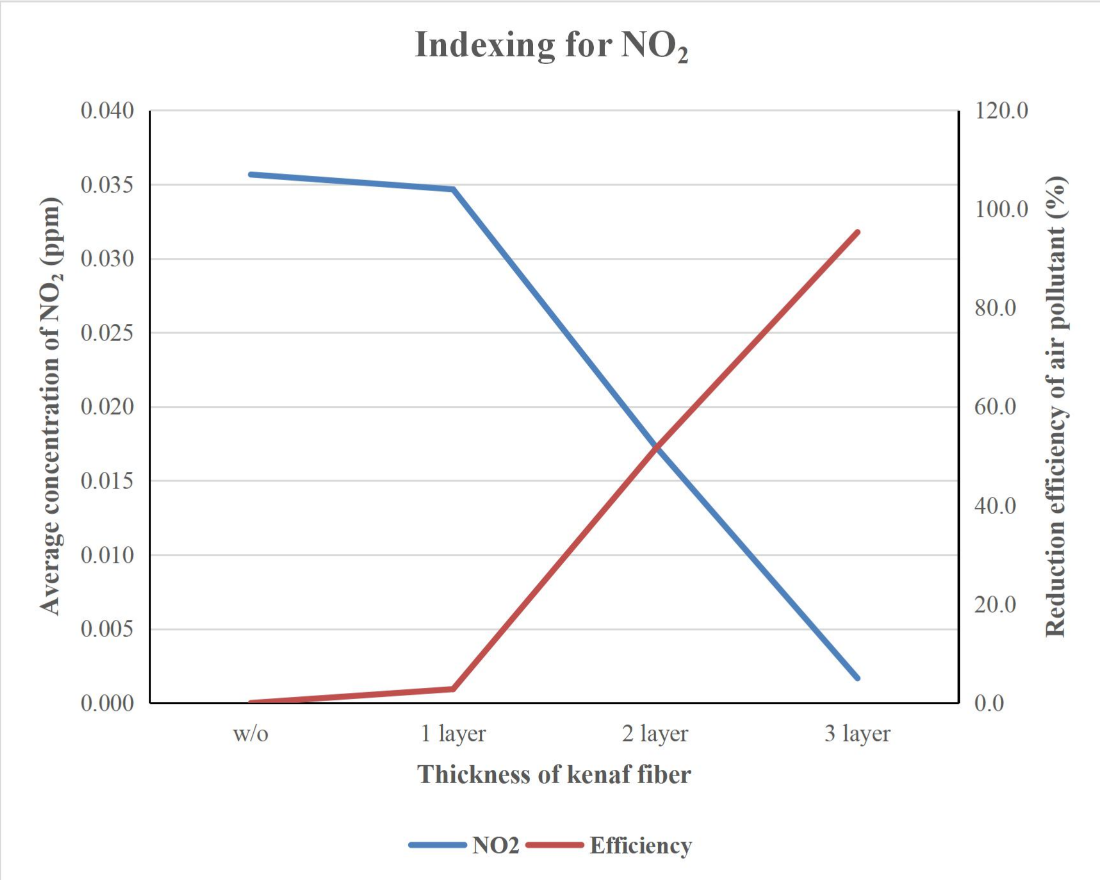

Figure 4.8 Safe environment index of NO_2

The figure above shown that kenaf fiber has the ability in reducing the gas of NO_2 that present in the air from the bauxite sample. The effectiveness in reducing NO_2 was increased continuously as the thickness of kenaf fiber increased. The average concentration of NO_2 was 0.036ppm when no kenaf fiber was applied and it reduce to 0.002ppm when 3 layers of kenaf fiber was applied on top of the bauxite sample. The maximum reduction efficiency was 95.3% when 3 layers of kenaf fiber was applied in the system. According to Etim *et al.* (2018), a H atom that attached by the electronegative atom such as O and F atom is known as hydrogen bond donor. However, hydrogen bond acceptor also known as proton acceptor is occurred when the electronegative atom did not covalently attach to the H atom in the hydrogen bonding. This will occur when the carbon atom in the C-H bonds of hydrogen bonding bounded to electronegative substituents such as nitrogen (N) and O atom to form an ionic compound.

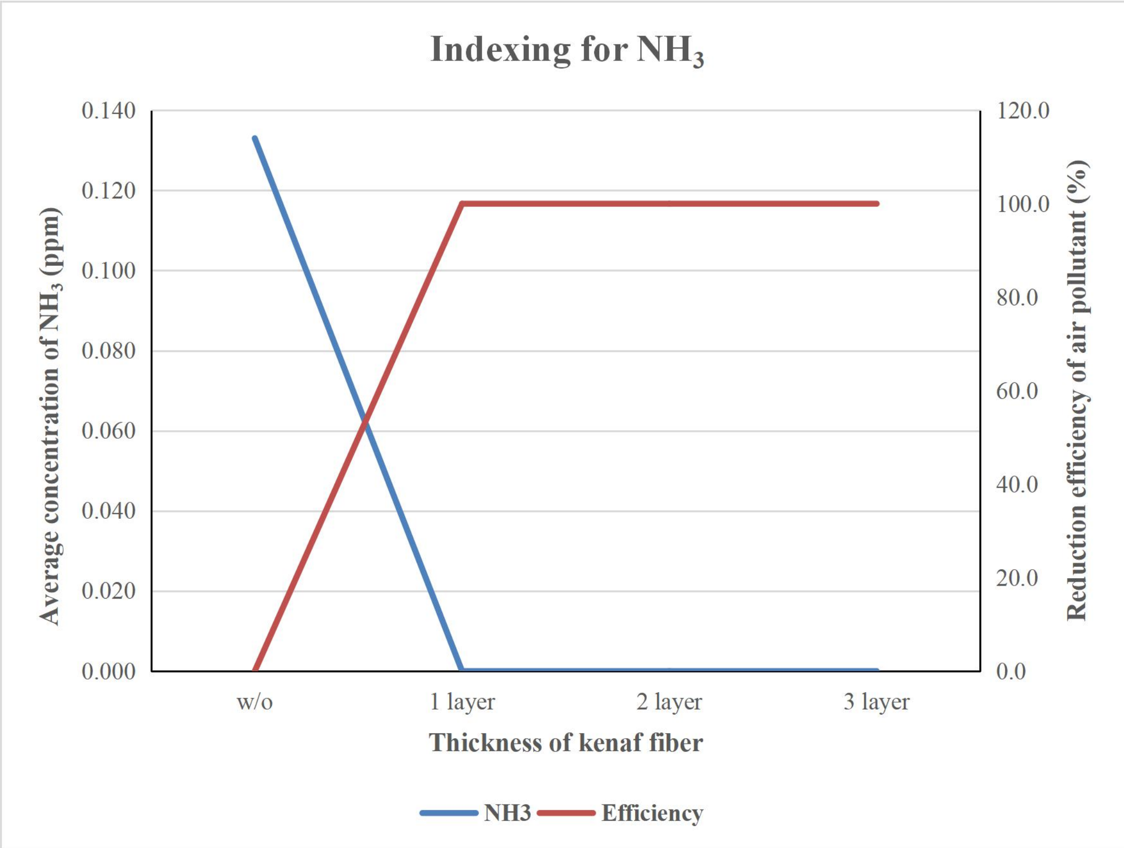

Figure 4.9 Safe environment index of NH_3

The figure above shown that kenaf fiber has the ability in reducing the gas of NH_3 that present in the air from the bauxite sample. The effectiveness in reducing NH_3 was increased continuously as the thickness of kenaf fiber increased. The average concentration of NH_3 was 0.133ppm when no kenaf fiber was applied and it reduce to 0ppm when 3 layers of kenaf fiber was applied on top of the bauxite sample. The maximum reduction efficiency was 100% when 3 layers of kenaf fiber was applied in the system. According to Ramesh (2016), Kenaf fiber is intended to absorb moisture content in atmosphere through hydrogen bonding due to the hydroxyl and oxygen containing group in the cell wall polymer of Kenaf fiber. Accoring to Etim *et al.* (2018), hydrogen bonding is well recognized and with great contribution to various industries such as determining the basic structure of large bio-molecules in DNA, RNA, proteins and others where it is a partially electrostatic attraction between hydrogen (H) atom with electronegative atom such as oxygen (O) and fluorine (F) atoms. The hydroxyl and oxygen containing group in the cell wall provided an attraction of electronegativity to the H atom inside the NH_3, where this statement validates the result of research as the Kenaf fiber absorbed NH_3 completely in the system. According to Etim *et al.* (2018), a H atom that attached by the electronegative atom such as O and F atom is known as hydrogen bond donor. However, hydrogen bond acceptor also known as proton acceptor is occurred when the electronegative atom did not covalently attach to the H atom in the hydrogen bonding. This will occur when the carbon atom in the C-H bonds of hydrogen bonding bounded to electronegative substituents such as Cl_2 and form a new element which is chloroform ($CHCl_3$).

CHAPTER 5

CONCLUSION

5.1 Introduction

The objectives of this research achieved which were to study the reduction of air pollutants concentration by using different thickness of *Hibiscus Cannabinus L.* (Kenaf) and the influence of wind speed and to propose the safe environment index for different thickness of *Hibiscus Cannabinus L.*(Kenaf) in air pollutants reduction. The main parameter in this research were the thickness of kenaf fiber and wind speed in affecting the air pollutants concentration caused by the bauxite sample. Kenaf fiber acted as an effective air pollutants filter in this research which able to reduce the air pollutants concentration. For this research, the conclusion has been drawn as follow:

In condition of wind speed level 3, the average concentration of PM_{10} was reduced continuously as the thickness of kenaf fiber increased. The reduction of concentration of PM_{10} was from 0.028mg/m^3 to 0.021mg/m^3, 0.014mg/m^3 and 0.012mg/m^3 with one layer, two layers and three layers of kenaf fiber respectively. The PM_{10} concentration reduction efficiency was raised as the thickness of kenaf fiber increased. The maximum reduction efficiency was 57.1% for PM_{10}. It can conclude that the kenaf has the ability in reducing the particular matter.

In condition of wind speed level 3, the average concentration of Cl_2 was reduced continuously as the thickness of kenaf fiber increased. The reduction of concentration of Cl_2 was from 0.049ppm to 0.021ppm, 0.006ppm and 0.002ppm with one layer, two layers and three layers of kenaf fiber respectively. The Cl_2 concentration reduction efficiency was raised as the thickness of kenaf fiber increased. The maximum reduction efficiency was 95.9% for Cl_2. This can be concluded that the kenaf fiber can reduce the Cl_2 effectively.

In condition of wind speed level 3, the average concentration of NO_2 was reduced continuously as the thickness of kenaf fiber increased. The reduction of concentration of NO_2 was from 0.069ppm to 0.058ppm, 0.034ppm and 0.011ppm with one layer, two layers and three layers of kenaf fiber respectively. The NO_2 concentration reduction efficiency was raised as the thickness of kenaf fiber increased. The maximum reduction efficiency was 84.1% for NO_2 means that NO_2 can be filtered by using kenaf fiber.

In condition of wind speed level 3, the average concentration of NH_3 was reduced continuously as the thickness of kenaf fiber increased. The reduction of concentration of NH_3 was from 0.367ppm to 0ppm for all layer stage of kenaf fiber. The NH_3 concentration reduction efficiency was raised as the thickness of kenaf fiber increased. The maximum reduction efficiency was 100% for NH_3 shown the kenaf fiber has a great performance in reducing NH_3.

As the wind speed increased, the concentration of air pollutants increased. At wind speed 1,the concentration of PM_{10} was 0.020mg/m^3 and increased to 0.024mg/m^3 and 0.028mg/m^3 in wind speed level 2 and 3 respectively. Next, the concentration of Cl_2 was 0.017ppm and increased to 0.037ppm and 0.049ppm at wind speed 2 and 3 respectively. Whereas for NO_2, concentration of 0.036ppm, 0.052ppm and 0.069ppm was obtained at wind speed 1, 2 and 3 respectively. Lastly, the concentration of NH_3 was 0.133ppm at wind speed 1 and it increased to 0.233ppm and 0.367ppm at wind speed 2 and 3 respectively. Furthermore, NH3 has the highest amount of concentration of 0.367ppm at the highest wind speed among PM_{10}, Cl_2 and NO_2. This can be concluded that the bauxite sample contained high amount of ammonia as compared to the other substances. Besides that, it also can be concluded that wind helped in activated the harmful air particles to dispersed into the air or environment.

The efficiency of Kenaf fiber in reducing concentration of PM_{10} was observed to be lower as compared with reduction efficiency of air pollutants such as NH_3, NO_2 and Cl_2. This might be because of the hydroxyl and oxygen containing group inside the cell wall polymers, which preferring to absorb moisture content in the atmosphere through hydrogen bonding (Ramesh, 2016).

Based on the safe environment index developed, it shown the relationship of kenaf fiber thickness, concentration of air pollutants and the air pollutants reduction efficiency. The concentration of air pollutants reduced as thicker kenaf fiber was applied hence the air pollutants reduction efficiency also increased.

5.2 Recommendation

From the experiment conducted, the concentration of the particular matter and harmful gases detected were very low. In order to get a more accurate result, it is recommended that the bauxite sample can be heated for few times in a small portion to remove the excessive moisture contain in it.

Furthermore, it is recommended that the kenaf fiber can go through further process to reduce the ash presence during the experiment as it would contribute dust into the air which might affect the experiment result.

Based on the indexing developed, it is recommended further research can be conducted to innovate an air pollution control product using kenaf fiber as the filtration system which can be apply in the factories or industrial areas especially in bauxite mining since this research proved that the ability of kenaf fiber in reducing the air pollutants.

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APPENDIX A
APPENDIX 1

Daily mean of temperature and wind speed for the year 2015, 2016 and 2017.
Source: Meteorological Department of Pahang.

Station : KUANTAN
Latitude : 3° 46' N
Longitude : 103° 13' E
Elevation : 15.2 m

Stnno	Year	Month	Day	24 Hour Mean Temperature (° C)	24 Hour Mean Wind (m/s)
48657	2015	1	1	25.9	2.7
48657	2015	1	2	25.5	2.4
48657	2015	1	3	26.7	2.4
48657	2015	1	4	25.2	2.0
48657	2015	1	5	26.5	1.8
48657	2015	1	6	25.9	1.6
48657	2015	1	7	25.5	1.5
48657	2015	1	8	23.9	1.7
48657	2015	1	9	23.4	1.8
48657	2015	1	10	24.9	1.6
48657	2015	1	11	25.4	1.9
48657	2015	1	12	26.5	2.1
48657	2015	1	13	25.9	2.8
48657	2015	1	14	25.1	2.3
48657	2015	1	15	25.7	2.6
48657	2015	1	16	25.3	2.4
48657	2015	1	17	25.1	2.5
48657	2015	1	18	25.6	2.6
48657	2015	1	19	25.3	2.4
48657	2015	1	20	25.1	2.2
48657	2015	1	21	25.8	2.5
48657	2015	1	22	24.9	2.2
48657	2015	1	23	25.2	2.3
48657	2015	1	24	25.6	2.0
48657	2015	1	25	25.7	1.9
48657	2015	1	26	25.8	2.2
48657	2015	1	27	25.7	1.9
48657	2015	1	28	26.1	2.2
48657	2015	1	29	24.6	1.7

48657	2015	1	30	25.7	2.2
48657	2015	1	31	25.7	2.8
48657	2015	2	1	25.2	2.8
48657	2015	2	2	24.5	2.2
48657	2015	2	3	24.3	2.9
48657	2015	2	4	24.1	2.4
48657	2015	2	5	25.2	2.3
48657	2015	2	6	25.0	2.4
48657	2015	2	7	25.1	2.4
48657	2015	2	8	25.0	2.3
48657	2015	2	9	24.6	2.5
48657	2015	2	10	24.9	2.9
48657	2015	2	11	25.2	2.4
48657	2015	2	12	25.1	2.4
48657	2015	2	13	24.9	2.4
48657	2015	2	14	25.1	2.1
48657	2015	2	15	26.0	1.7
48657	2015	2	16	26.5	2.1
48657	2015	2	17	26.4	2.0
48657	2015	2	18	26.5	2.4
48657	2015	2	19	26.4	1.6
48657	2015	2	20	25.9	1.9
48657	2015	2	21	25.8	1.6
48657	2015	2	22	26.7	2.2
48657	2015	2	23	26.9	2.1
48657	2015	2	24	26.7	2.0
48657	2015	2	25	26.5	1.8
48657	2015	2	26	26.3	1.6
48657	2015	2	27	27.0	2.0
48657	2015	2	28	27.0	2.1
48657	2015	3	1	27.3	2.4
48657	2015	3	2	27.2	2.2
48657	2015	3	3	27.8	2.1
48657	2015	3	4	27.1	1.6
48657	2015	3	5	26.4	1.5
48657	2015	3	6	27.0	1.6
48657	2015	3	7	27.2	2.0
48657	2015	3	8	28.1	2.2
48657	2015	3	9	28.0	2.4
48657	2015	3	10	27.5	2.3
48657	2015	3	11	27.5	2.9
48657	2015	3	12	26.7	2.4
48657	2015	3	13	25.9	2.4
48657	2015	3	14	26.8	2.4
48657	2015	3	15	27.0	2.1
48657	2015	3	16	27.5	2.1

48657	2015	3	17	28.5	1.9
48657	2015	3	18	28.6	1.8
48657	2015	3	19	28.8	1.9
48657	2015	3	20	28.4	1.4
48657	2015	3	21	27.8	1.6
48657	2015	3	22	28.0	1.7
48657	2015	3	23	27.6	2.0
48657	2015	3	24	27.1	2.4
48657	2015	3	25	26.8	2.0
48657	2015	3	26	27.9	2.8
48657	2015	3	27	28.0	2.5
48657	2015	3	28	28.4	2.4
48657	2015	3	29	28.0	2.1
48657	2015	3	30	27.0	1.8
48657	2015	3	31	26.4	1.2
48657	2015	4	1	27.4	1.3
48657	2015	4	2	26.1	1.2
48657	2015	4	3	27.7	1.4
48657	2015	4	4	28.6	1.3
48657	2015	4	5	28.6	1.3
48657	2015	4	6	28.7	1.7
48657	2015	4	7	28.8	2.0
48657	2015	4	8	29.0	2.1
48657	2015	4	9	28.3	2.4
48657	2015	4	10	27.4	1.7
48657	2015	4	11	28.0	1.5
48657	2015	4	12	28.0	1.7
48657	2015	4	13	28.4	1.9
48657	2015	4	14	27.9	2.0
48657	2015	4	15	27.5	1.6
48657	2015	4	16	28.0	2.0
48657	2015	4	17	28.6	1.8
48657	2015	4	18	28.8	1.3
48657	2015	4	19	28.5	1.4
48657	2015	4	20	28.4	1.5
48657	2015	4	21	27.9	1.7
48657	2015	4	22	28.4	1.4
48657	2015	4	23	28.9	1.8
48657	2015	4	24	28.5	1.8
48657	2015	4	25	26.9	1.2
48657	2015	4	26	28.4	1.8
48657	2015	4	27	26.8	1.1
48657	2015	4	28	27.9	1.6
48657	2015	4	29	27.7	1.1
48657	2015	4	30	27.1	1.3
48657	2015	5	1	28.0	1.3

48657	2015	5	2	26.8	1.3
48657	2015	5	3	26.7	0.9
48657	2015	5	4	28.3	1.6
48657	2015	5	5	27.8	1.8
48657	2015	5	6	27.9	0.7
48657	2015	5	7	29.2	1.2
48657	2015	5	8	29.5	1.8
48657	2015	5	9	28.5	2.3
48657	2015	5	10	28.9	1.3
48657	2015	5	11	28.4	1.5
48657	2015	5	12	28.7	1.3
48657	2015	5	13	29.3	1.6
48657	2015	5	14	28.8	1.4
48657	2015	5	15	27.9	1.1
48657	2015	5	16	28.6	1.1
48657	2015	5	17	27.7	1.7
48657	2015	5	18	27.2	1.5
48657	2015	5	19	28.3	1.6
48657	2015	5	20	28.4	1.4
48657	2015	5	21	28.3	1.2
48657	2015	5	22	28.3	2.1
48657	2015	5	23	27.9	1.2
48657	2015	5	24	28.6	1.6
48657	2015	5	25	27.8	1.6
48657	2015	5	26	26.8	1.0
48657	2015	5	27	28.0	1.6
48657	2015	5	28	28.0	1.7
48657	2015	5	29	27.8	1.3
48657	2015	5	30	29.0	1.6
48657	2015	5	31	28.6	1.1
48657	2015	6	1	28.3	1.0
48657	2015	6	2	28.0	1.3
48657	2015	6	3	27.7	1.1
48657	2015	6	4	28.3	1.0
48657	2015	6	5	28.8	1.0
48657	2015	6	6	28.6	1.1
48657	2015	6	7	28.9	1.4
48657	2015	6	8	28.2	1.9
48657	2015	6	9	27.0	0.9
48657	2015	6	10	28.3	1.3
48657	2015	6	11	28.4	1.6
48657	2015	6	12	27.5	1.6
48657	2015	6	13	26.9	1.3
48657	2015	6	14	27.2	2.0
48657	2015	6	15	27.2	2.3
48657	2015	6	16	27.0	1.7

48657	2015	6	17	27.8	0.9
48657	2015	6	18	27.3	1.3
48657	2015	6	19	28.1	1.8
48657	2015	6	20	28.7	2.0
48657	2015	6	21	29.5	1.8
48657	2015	6	22	29.5	1.8
48657	2015	6	23	29.4	2.1
48657	2015	6	24	29.2	1.7
48657	2015	6	25	28.6	2.0
48657	2015	6	26	28.8	1.5
48657	2015	6	27	29.5	2.2
48657	2015	6	28	29.7	2.0
48657	2015	6	29	29.0	1.1
48657	2015	6	30	28.8	1.0
48657	2015	7	1	28.0	1.3
48657	2015	7	2	28.7	1.9
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48657	2017	12	24	25.9	2.1
48657	2017	12	25	26.9	1.6
48657	2017	12	26	26.7	1.1
48657	2017	12	27	25.3	1.7
48657	2017	12	28	26.7	2.0
48657	2017	12	29	25.4	2.3
48657	2017	12	30	26.5	2.6
48657	2017	12	31	25.1	2.2

Note : MST - Malaysian Standard Time

Definition : -1.1 - Defective Value

APPENDIX B
APPENDIX 2

Average wind speed and temperature for the year 2015, 2016 and 2017.

	Temperature	Wind speed
Average 2015	27.3	1.6
Average 2016	27.6	1.6
Average 2017	27.0	1.7