The Influence of Meteorological Variables on Air Pollutants Improvement using Hibiscus Cannabinus L. Kenaf Filter

Suryati Sulaiman, Noor Suraya Romali, Abd Syukor Abd Razak, Rokiah Othman

Abstract*: Bauxite mining activities has led to serious consequences towards humans and environment in term of water pollution, air pollution and has extensively damaged the ecosystem of aquatic life. This study investigates the performance of Hibiscus Cannabinus L. (Kenaf) fibres in improving air pollutants. The influence of meteorological conditions i.e. temperature and wind speed, as well as the thickness of Kenaf fibre filter on the concentration of PM_{10}, NH_3, NO_2, and Cl_2 after the Kenaf fiber treatment is established. The bauxite sample was collected near Kuantan Port, Pahang and a prototype was fabricated to test ability of the Kenaf fibres in improving air quality. Wind speed and temperature was modified to be similar as the actual conditions on site. The study found that the Kenaf fibre filter improved the concentration of PM_{10}, NH_3, NO_2, and Cl_2 efficiently after air treatment. Two layers of Kenaf fiber filter showed better performance in removing air pollutants as compared to one-layer filter. One-layer filter is capable to improve 16% to 43% of PM_{10}, NH_3, NO_2, and Cl_2 concentration, whereas as high as 70% of pollutants can be removed when two-layer filter is utilized. The removal efficiencies of NH_3, NO_2, Cl_2 and PM_{10} (with Kenaf) increased from 33%, 17%, 38% and 75% to 60%, 67%, 73% and 85% respectively when the wind speed increased from 900 rpm to 1200 rpm. In contrast, the percentages of removal decreased when higher temperature was applied. The removal of PM_{10}, NH_3, NO_2, and Cl_2 decreased from 75%, 60%, 69% and 41% to 57%, 50%, 65% and 39% respectively when the temperature was increased from 27 °C to 32 °C.

***Keywords* : Bauxite mining, air pollution, Kenaf fibres, temperature, wind speed.**

I. INTRODUCTION

Bauxite mining activities in Pahang, particularly in Kuantan has led to serious consequences to people around and the surrounding environment due to air and water pollution. Besides that, it has also effected vegetation of plants or trees. When the vegetation of plants and trees are affected, the habitat in the forest will also be greatly affected. This is due to the dust produced during transportation of bauxite from mining site to the stockpile storage at Kuantan port [1]. It is believed that road transportation is one of the source of air pollution in urban areas [2]. On the other hand, bauxite mining also has serious public health consequences. This is due to the fact that destruction of natural habitat eventually threatens our access to most fundamental requisites for human existence such as safe and clean water, safe food and shelter. The polluted ecosystems have great potential to create chronic and unpredictable exposures, leading to direct or indirect, immediate and long-term potential impacts on health [3].

The community is being troubled with the issue of air pollution. In order to open a mining, clearing and removal of land is required. The excavating process, removal of top soil and vegetation, transportation of bauxite and unwanted elements and stockpile of bauxite can cause degradation of air quality. It is mainly related to dust pollution caused by meteorological characteristics of Kuantan Port. Dust is a solid particulate matter, with its size ranging from 1 to 75 microns in diameter. Dust smaller than 10 micrometers in diameter, known as particulate matter PM_{10} and $PM_{2.5}$ are of great health concern because it can be inhaled into the respiratory system [4].

Research and development activities are being carried out continually to develop new technologies for air pollution reduction. This is because global mind about a pollution-free environment is built-up due to the campaign and activities that awaken the awareness of worldwide citizens. Recently, people are more preferring to use natural fiber products which not only achieve intended purpose but also environmentally friendly because forests are impossible to produce an annual quantity of fiber to meet domestic demand of the world market, non-woods have become one of the major alternative sources of fibrous material for 21st century [5].

Application of Kenaf fiber is considered as environmental friendly due to its ability in absorbing CO_2 during their growth. The CO_2 produced from the decomposition and combustion of the natural fiber composites at the end of their life cycle is found could be neutralized by the absorption of CO_2 during growth of Kenaf plant. Also, natural fibers are found to be combusted easily compared to man-made fibers because man-made fibers have low energy values and high ash content which might aggravate the burden of environment thus causing air pollution [6].

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Kenaf is considered as an important fiber crop among numerous industries such as paper pulp, textile and others [5]. In Asia, Kenaf was first cultivated and utilized in India around 1990 but Kenaf is now used in commercial for more than 20 countries such as China, India and Thailand. China, India and Thailand cover for around 90% of the global area of Kenaf cultivation and produce more than 95% of worldwide Kenaf product [7]. Kenaf has been deemed extremely environmental friendly and very high interests in kenaf cultivation in recent years are because Kenaf is able to accumulate carbon dioxide at a significantly high rate and it able to absorb nitrogen and phosphorous from the soil [6].

A strategy to overcome the environmental issues at the study area is crucial. Kenaf fibre filter was introduced as a solution towards the problems. The Kenaf filter can be used to filter away all the unwanted air pollutants to provide a better quality of air.

II. MATERIALS AND METHODS

The main aim of this study was to reduce air pollutant levels in Kuantan Port where the ability of Kenaf fibre to filter the air pollutant in the air was tested. The bauxite sample was collected from Kuantan Port, Gebeng, Pahang, Malaysia. The sample was from the stockpile of bauxite that was gathered in the port before being shipped out.

A. Experimental Set-up

A prototype model was built (Fig. 1) by controlling two important factors which were temperature and wind speed. The controlled data of temperature and wind speed was obtained from Pahang's meteorological department. The prototype was designed in rectangular shape with dimensions of 1.0m x 0.5m x 0.5m.

Fig. 1. Prototype design

Fig. 2. Experimental set-up

There was an opening for the sample input and another opening for the fan, for the wind speed controlling purposes, as shown in Fig. 2. The opening of the prototype was designed to be almost as the size of the fan. Fan was the artificial wind representing the parameter of wind speed. There was another opening for the bauxite sample to be placed. Another important part in the prototype was the fibre filter holder. The filter holder was located after the bauxite sample in order to filter the air pollutant. At the other end of the prototype, an opening for the dust detector to be placed was made. A flow which was similar with a basic air filtration system was built within the prototype.

Before the experiment, bauxite sample obtained from the site was dried till the water was eliminated. The weight before and after the heating process of bauxite sample was recorded. The bauxite sample was placed at the bottom of prototype. Height of sample was about 6 cm. Kenaf sample with different thickness and different arrangements were set up on top of the bauxite sample.

B. Kenaf Fibre Filters

Kenaf is a type of plant also known as Hibiscus Cannabinus L. (Fig. 3). It is a plant that can be developed into useful natural fibre. It can be used to make ropes, twines and sackcloth. It can also be used as paper products, building materials, absorbents and livestock feed [5]. Among other useful applications of Kenaf, it can be used to make a type of fibre layer that can filter air pollutant. It eventually can turn into a product that will solve air pollution issue in the future keeping in mind the advantages that it can provide to public health.

Fig. 3. Hibiscus Cannabinus L. (Kenaf) plants

In this study, the sample of Hibiscus Cannabinus L. (Kenaf) fiber was taken at a Kenaf processing plant in Terengganu to function as air filter to reduce air pollutants produced by bauxite mining. The Kenaf fiber was fabricated into rectangular layer. Fig. 4 (a) and (b) shows the top view and side view of Kenaf fiber used in this study respectively.

(a)

(b)

Fig. 4. a) Top view and (b) side view of Kenaf fibre used in the experiment

C. Tested Parameters

Most important parameter in this research was particulate matter 10 micrometers (PM_{10}). Particulate matter was one of the important factors to determine the ability of Kenaf fibres in removing air pollutants. Particulate matter (PM) can be explained as dispersed matter, solid or liquid, size between 0.002µm to 500µm in diameter that exist in atmosphere. PM is broadly categorized by aerodynamic diameter: All particles with size smaller than 10µm considered as thoracic particles (PM_{10}), particles with size smaller than 2.5µm considered as fine particles ($PM_{2.5}$), particles smaller than 0.1µm are known as ultrafine particles (UPF) where particles sizes between 2.5µm and 10µm considered as coarse particles ($PM_{10-2.5}$) [8]. The typical particulate matters are dust, smoke, fumes, fly ash, mist and spray and the major source throughout the world for particulate matters come from the combustion of fossil fuels especially from activities of industry, transportation and fossil fuels fired power plants [9].

This parameter was specially detected by the dust detector. Concentration from the dust detector was being recorded for each hour for 24 hours. The peak and average concentration of PM_{10} was recorded for each hour. In addition, concentration of particulate matter on the prototype before applying Kenaf fibres and also the concentration of particulate matter on the prototype after the application of Kenaf fibres was compared. Particulate matter was determined by dust detector available in Environmental Laboratory, University Malaysia Pahang.

For other parameters such as Ammonia (NH_3), Nitrogen Dioxide (NO_2), and Chlorine (Cl_2), they were detected by the gas detector. Gas detector were placed at the end of the prototype to enable the detector to react towards these harmful substances. Concentration from the dust detector was being recorded for each hour for 24 hours. The peak and average concentration of harmful substances were recorded for each hour.

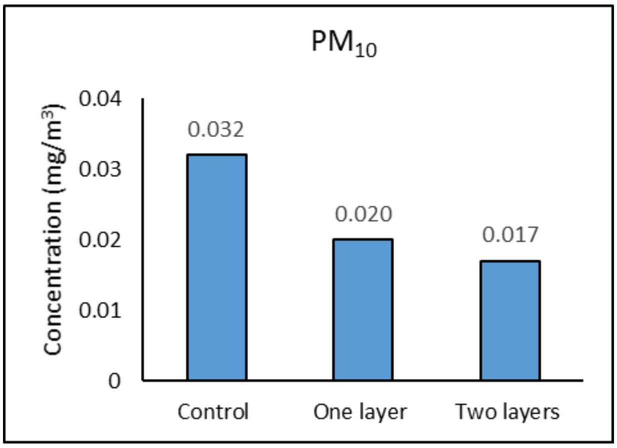
D. Tested Variables

Two meteorological variables were tested to observe the performance of air pollutant removal in this study i.e. wind speed and temperature. The fan was used to simulate artificial wind for testing of wind speed. Wind speed of the fan was controlled for different wind speeds of 900, 1050 and 1200 rpm. On the other hand, temperature was controlled by air conditioner in the closed room where the experiment was conducted. Range of temperature chosen for this study was 27 ^{o}C and 32 ^{o}C. The value was based on the average value in Pahang for the year 2015, 2016 and 2017. Average temperature for the past 3 years is 27 to 28 ^{o}C, while the highest temperature is 32 ^{o}C.

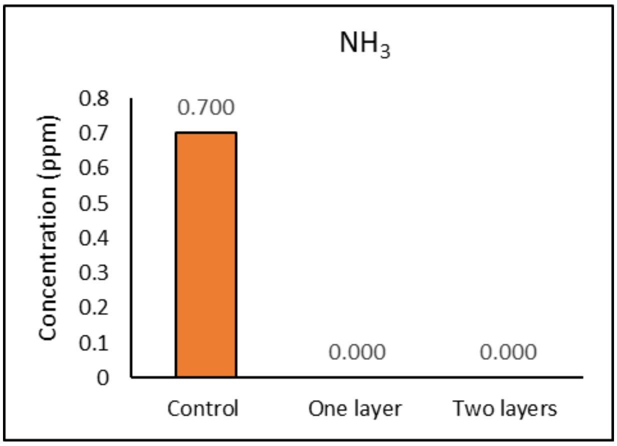
III. RESULTS AND DISCUSSIONS

A. Air Pollutants Improvement using Kenaf Fibre

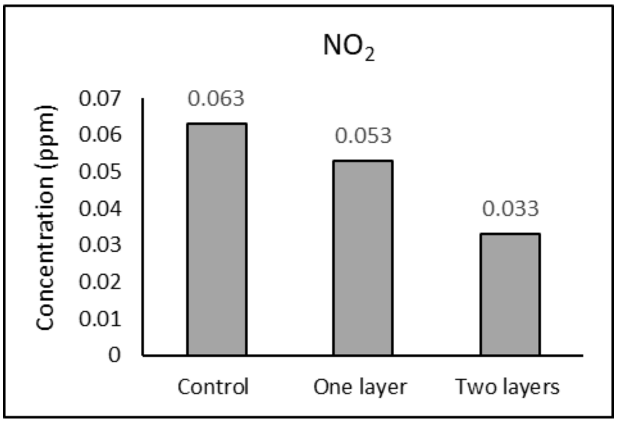
Fig. 5 (a) to (d) shows the concentration of PM_{10}, NH_3, NO_2, and Cl_2 respectively, with the use and absence (control) of Kenaf fibres.



(a)



(b)



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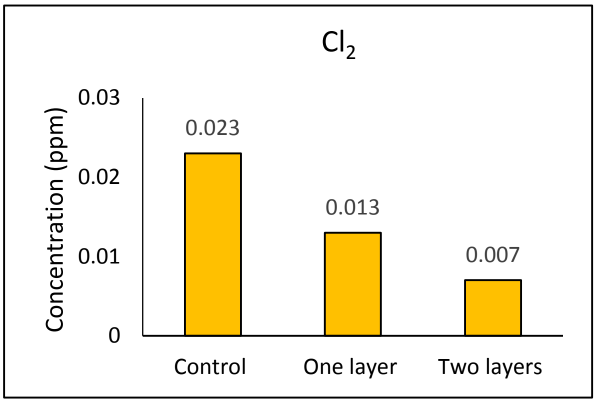

(d)

Fig. 5. The concentration of (a) PM_{10}, (b) NH_3, (c) NO_2 and (d) Cl_2 after Kenaf fibre treatment

It can be seen that concentration of all the parameters reduced after Kenaf fiber treatment. Concentration of PM_{10} is reduced from 0.032 mg/m^3 to 0.020 mg/m^3 and 0.017 mg/m^3 for one and two layers of Kenaf fibre respectively (Fig. 5 (a)). The improvement is approximately 75% to 85%, while for NH_3, NO_2, and Cl_2 the percentages of removal are approximately 20% to 70%. Highest removal can be observed in Fig. 5 (b) for parameter NH_3 where the concentration is improved from 0.7 ppm to almost 0 ppm when Kenaf filter was used. It clearly showed that the Kenaf fibers are efficiently filtering all the impurities in the air caused by the bauxite sample.

In addition, the results demonstrated that two layers of Kenaf fiber shows a better performance in removing air pollutants compared to one-layer filter. As mentioned earlier, the treatment of PM_{10} using two layers of Kenaf fiber shows lowest concentration value of 0.017 mg/m^3 compared to one layer (0.020 mg/m^3). Similar trend is observed for parameters NH_3, NO_2, and Cl_2. The concentration of NO_2 is reduced by 16% from 0.063 ppm to 0.053 ppm when one-layer filter is applied (Fig. 5 (c)). However, treatment using two-layer filter resulted in a lower concentration i.e. 0.033 ppm, which is almost 48% removal. Concentration of Cl_2 improved from 0.023 ppm to 0.013 ppm with one-layer filter treatment, and decreased to as low as 0.007 ppm which is 70% removal when two-layer filter is applied, as seen in Fig. 5(d). Overall, it is clear that when the thickness of Kenaf fiber was increased, it can filter more pollutants emitted from the bauxite sample. One-layer Kenaf fibre filter is capable to improve 16% to 43% of PM_{10}, NH_3, NO_2, and Cl_2 concentration, whereas as high as 70% of the pollutants can be removed when two-layer filter is applied.

B. Effects of Different Wind Speeds to Air Pollutants Improvement

As shown in Fig. 6, the efficiency of removing air pollutants increased with increasing wind speed. The removal efficiency of PM_{10} after Kenaf treatment increased from 75% at wind speed of 900 rpm to 85% at wind speed of 1200 rpm. Similar trend can be observed for NH_3, NO_2 and Cl_2. The removal efficiencies of NH_3, NO_2 and Cl_2 (with Kenaf) increase from 33%, 17% and 38% to 60%, 67% and 73%, respectively when the wind speed increased from 900 rpm to 1200 rpm. It shows that concentration of the particulate matter is highly emitted when the wind speed was at 1200 rpm. The higher wind speed distributed the air pollutants thus increasing the level of air pollution.

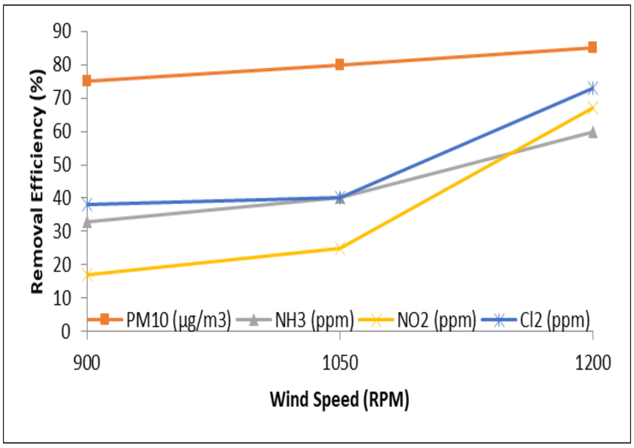

Fig. 6. The profile of air pollutants removal efficiencies at different wind speed

Higher concentration of NH_3, NO_2, and Cl_2 indicated that the bauxite sample was affected by drastic change in wind speed during actual conditions. The particles were dispersed into the air by wind speed. 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 causing air pollution. The particle gained energy from surrounding temperature causing it to be in active state. With the help of wind speed, active particles can easily be dispersed into the air [10]. Besides that, the wind speed is also dependent on the location or area. The location of this research is at Kuantan Port, where the wind speed is relatively higher compared to other places.

C. Effects of Different Temperature to Air Pollutants Improvement

Fig. 7 compares removal percentage of air pollutants after Kenaf treatment according to various temperature at 27 °C and 32 °C.

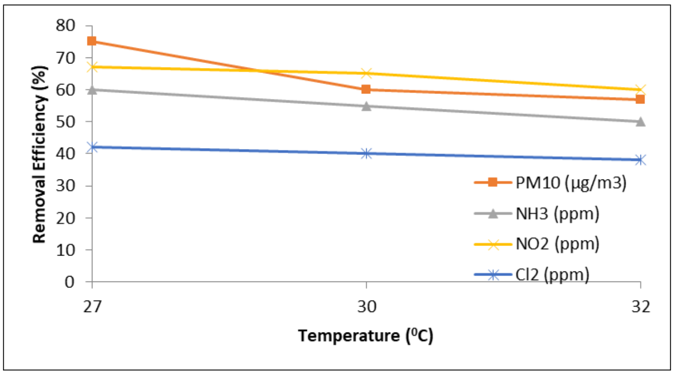

Fig. 7. Percentages of removal for parameters PM_{10}, NH_3, NO_2, and Cl_2 according to various temperature at 27 °C and 32°C

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The percentages of removal decreased when higher temperature was applied. As observed in Fig. 7, removal efficiency of PM_{10} decreased from 75% to 57% as the temperature increased from 27 °C to 32 °C. Similarly, the percentages of removal for NH_3, NO_2, and Cl_2 decreased from 60%, 69% and 41% to 50%, 65% and 39%, respectively when the temperature increased from 27 °C and 32 °C. This result is in agreement with Kalisa et al. [11] who found that the concentration of PM_{10} and NO_2 increased as the temperature increased, in their study to investigate the relationship between temperature and air pollution during heatwaves in Birmingham, UK.

IV. CONCLUSION

In this study the application of Kenaf fiber to improve air pollution is investigated. The effect of wind speed and temperature, as well as thickness of Kenaf fibre filter to the performance of Kenaf fiber as air pollutant treatment is tested. The findings of this study in relation to research objectives are as follows;

i. Kenaf fibre filter is capable to improve concentration of PM_{10}, NH_3, NO_2, and Cl_2 efficiently after air treatment. Two layers of Kenaf fiber filter shows a better performance in removing air pollutants compared to one-layer filter. One-layer filter is capable to improve 16% to 43% of PM_{10}, NH_3, NO_2, and Cl_2 concentration, whereas as high as 70% of the pollutants can be removed when two-layer filter is applied.

ii. The removal efficiency of PM_{10} after Kenaf treatment increased from 75% at wind speed 900 rpm to 85% at wind speed of 1200 rpm. The removal efficiencies of NH_3, NO_2 and Cl_2 (with Kenaf) increased from 33%, 17%, and 38% to 60%, 67% and 73% respectively when the wind speed increased from 900 rpm to 1200 rpm.

iii. The percentages of removal decreased when higher temperature was applied. The concentration of PM_{10} decreased from 75% to 57% as the temperature increased from 27 °C to 32 °C. Similarly, the removal of NH_3, NO_2, and Cl_2 decreased from 60%, 69% and 41% to 50%, 65% and 39% respectively when the temperature increased.

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AUTHORS PROFILE

Suryati Sulaiman is a dedicated lecturer within the Faculty of Civil Engineering Technology, Universiti Malaysia Pahang (UMP). Her primary research activities involve the area of environmental engineering (water and wastewater treatment engineering) and environmental management. She has been a lecturer since 2002 and has been lecturing in Water Treatment Engineering, Wastewater Treatment Engineering, Environmental Management, Environmental Engineering and Advanced Water and Wastewater Treatment ever since. She has published a few technical papers in her research area. She is actively in doing research. She has been awarded Cendekia Bitara Awards 2017 for her initiative to patent her research innovation in the area of corrosion inhibiting composition and method. In the past 3 years, her research focusses on the application of kenaf fibre especially in reducing air pollutants and has been won Gold Medal during ITEX 2019.

Noor Suraya Romali obtained her first degree in B.Eng. in Civil Engineering from Universiti Malaysia Sarawak. She received her M.Eng. in Hydrology and Water Resources Engineering and completed her doctoral study (in Civil Engineering) from Universiti Teknologi Malaysia. Her primary research interest includes flood damage assessment, flood modeling, flood risk assessment and hydro-environment research. She has already published more than 25 articles, journals and conference proceedings and has secured more than 10 research grants as principal investigator and research member.

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Rokiah Othman was a graduate of UiTM Shah Alam in Bachelor and Master in Civil Engineering. In July 2005, she joined Faculty of Civil Engineering & Earth Resources and since then she was appointed as Head of Diploma Programme (2008-2011) and currently she is the Promotion coordinator and co-editor for faculty's magazine. Her teaching and research areas include structure and materials, IBS, sustainability & green technology, geotechnical and environmental. She believes that every student can flourish if appropriately challenged, stay positive, supported and enjoy the campus experiences.