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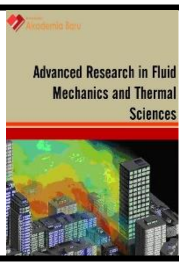


# Production of Bio-Sorbent from Banana Peel (*Musa acuminate L*) Activated with $ZnCl_2$ for Carbon Monoxide Gas Emission Adsorption from Motor Vehicles

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**ABSTRACT**

Banana peel is one of the agricultural waste that is easily obtained, inexpensive, and can be prepared as environmentally friendly bio-sorbents. The purpose of this study was focused on producing bio-sorbent from banana peel waste (*Musa acuminate L*) with a chemical activation process using $ZnCl_2$ activator as an absorber for motor vehicle exhaust gas emissions. The dried peels were carbonized in the furnace at a temperature of 400°C for 1.5 hours and followed by chemical activation using $ZnCl_2$ at variation of concentration 1, 2, and 3 N during 1, 2, and 3 hours, respectively. Characteristics of bio-sorbent produced were identified using Fourier Transform-Infra Red (FTIR) and Scanning Electron Microscope (SEM). Results showed that bio-sorbent characteristics of banana peel (*Musa acuminate L*) activated by $ZnCl_2$ still meet the technical activated carbon quality requirements based on Indonesian National Standard (SNI 06-3730-1995) with a moisture content of 5.40-10.70%, ash content of 6.10-9.00%, and volatile matter 5.60-10.40%. The FTIR surface test results showed that bio-sorbent had an absorption of C-O, C=C, and C-H functional groups. On the bio-sorbent surface of the banana peel which has been activated with $ZnCl_2$ appeared with a larger pore diameter (12.872-28.566 µm) when compared to the bio-sorbent surface before activation. Bio-sorbent of banana peel (*Musa acuminate L*) activated by $ZnCl_2$ can adsorb CO gas emission levels up to 44%.



## 1. Introduction

Banana peel is one of the agricultural wastes which is widely disposed of as a material that is less useful and can cause environmental problems. Banana peels have potential as composting, cosmetics and sorbents materials as environmentally friendly bio-material that is cheap and easy to obtain. Banana skin contains a large amount of starch, protein, and fiber which can be used as a source of energy from biomass. At present, banana peels have not been fully utilized as a useful raw material

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in producing high-value products such as bio-sorbent. Bio-sorbent can be prepared through some stages up to that biomaterial that can be used to absorb heavy metals in water phase [1].

Several studies have reported the use of activated carbon from biomaterials residual from wood powder, leaves, cocoa, oil palm bunches, banana weeds and other biomass for the absorption of heavy metals, methylene blue, taste and dour in liquid waste. Activated carbon from biomaterials can also be used as gas purification, catalysts, filters and deodorizing agents in the medicine, food and water treatment industries, water filtration, and re-usable solvents [2-4].

Environmental pollution problem has been a hot issue discussed in recent years due to the increase of solid waste accumulation, both organic and inorganic waste. Not only the solid waste problem but also the level of air pollution that continues to increase due to population activities, such as emissions from motor vehicles. The increasing number of the population followed by the development of transportation equipment, especially highways has caused vehicle fumes which have hurt the lives of living things and the environment. The emission of transportation equipment produces toxic gases from millions of motorized vehicles every day which has an impact on decreasing air quality and resulting in various chronic diseases if inhaled by humans. Besides harmful to human health, it also causes the effects of greenhouse gases which result in increasing global warming on this earth.

Some researchers reported that banana peels could be prepared into bio-sorbent to absorb $CO_2$ gas emissions in the environment [5,6]. Activated carbon from banana peel was identified having the highest activated carbon yield with surface area (260.38 $m^2$/gr), total pore volume (0.016 $cm^3$/gr) and pore diameter (0.251 nm). Synthesized banana peel bio-sorbent can effectively remove $CO_2$ gas up to 1.65% by weight of $CO_2$ through the adsorption process at 25$^o$C. Furthermore, Hossain *et al.,* [7] produced activated carbon from banana peel biomass with several activators through chemical processes. However, $H_3PO_4$ and KOH are more widely used as activators in producing activated carbon because of low energy costs and high carbon yields. Ahmad *et al.,* [8] have examined several biomass which can be used as bio-sorbents, the stages of preparing bio-sorbents generally begin with carbonization and then proceed with a chemical activation process. They reported that the advantages of chemical activation methods compared to physical activation are: (i) one step process; (2) carried out at lower temperatures and has a better effect on the formation of pores; and (iii) higher carbon yields and lower energy costs. Several other researchers have used chemical activation methods for the production of activated carbon. In chemical activation, biomass is impregnated in various activator chemicals such as phosphoric acid ($H_3PO_4$), zinc chloride ($ZnCl_2$), potassium hydroxide (KOH), sulfuric acid ($H_2SO_4$), hydrochloric acid (HCl), nitric acid ($HNO_3$), pyro phosphoric acid ($H_4P_2O_7$), sodium hydroxide (NaOH), sodium chloride (NaCl), potassium carbonate ($K_2CO_3$), ammonium chloride ($NH_4Cl$), sodium carbonate ($Na_2CO_3$), iron chloride ($FeCl_3$), hydrogen peroxide ($H_2O_2$), and others activators.

At present, the literature that reports on the use of banana peels as bio-sorbent to absorb vehicle emissions is still limited, so it is still necessary to conduct research on vehicle exhaust gas absorption using bio-sorbents. Motorized vehicles emit combustion products in the form of exhaust gases containing various pollutants (CO, HC, $SO_2$, $NO_2$, and dust) which are generally dangerous gases. Further research to obtain bio-sorbents that are safe, effective and efficient in absorbing motorized vehicle emissions is still needed. The purpose of this study was focused on producing bio-sorbent from banana peel waste (*Musa acuminate L*) with a chemical activation process using $ZnCl_2$ activator as an absorber of motor vehicle exhaust gas emissions and obtaining bio-sorbent adsorption efficiency against exhaust gas emissions.

## 2. Material and Methodology

### *2.1 Materials*

Banana peel (*Musa acuminate L*) waste used in this study was obtained from the market was collected from Banda Aceh City traditional market. Chemicals such as $ZnCl_2$, amilum powder, iodine, and sodium thiosulfate used in this research was obtained commercially from Waco, LTD, p.a. grade chemicals.

This study were used some equipment such as oven (Memmert), drop pipettes (Hilgenberg GmbH), furnace (Thermocline Line FB1410M-33 at 1100$^o$C), scales (Ohaus), mesh sieves (Frame Stainless Steel), burette, static, porcelain, Fourier Transform-Infra Red (Shimadzu IR Prestige 21) and Flue gas Analyzer (Sensonic 6000).

### *2.2 Active Carbon Preparation and Test*

Banana peel cut into pieces of ± 3 cm and dried in the oven 60$^o$C for removing moisture contents. The dried peels were carbonized in the furnace at a temperature of 400$^o$C for 1.5 hours to become carbon (charcoal). Carbon was mashed and sifting with 100 mesh sieves. Carbon was activated chemically using $ZnCl_2$ solution by soaking it at variation concentration of 1, 2, and 3 N for 1, 2, and 3 hours, respectively. Carbon was filtered and washed thoroughly with aquadest until neutral pH was reached and then heated at 200$^o$C for 2 hours. Bio-sorbent produced then mixed with adhesive and then molded with a size of 1 cm length, 1 cm wide, and 1 cm high. After solid and hard in the form of pellets, bio-sorbent was heated in an oven for 2 hours at 80$^o$C. Characteristics of bio-sorbents were analyzed by measuring the moisture content, ash content, fixed carbon, and volatile matter using ovens and furnaces. Then, continued with iodine sorption measurements and functional group analysis using Fourier Transform-Infra Red (FT-IR). The surface pores of bio-sorbent formed was also observed using a Scanning Electron Microscope.

### *2.3 Absorption of Exhaust Gas Emissions*

Measurement of motorcycle gas emissions was conducted by mounting the tested vehicle in a flat position. Engine acceleration was conducted at the idle condition with 800 rpm to 1400 rpm engine rotation as manufacturer recommendation. The adsorption tube containing bio-sorbent was connected to the vehicle's exhaust, and the CO gas emission was analyzed by Emissions Analyzer (Sensonic-60000).

## 3. Results

### *3.1 Characteristics of Bio-Sorbent from the Banana Peel (Musa Acuminate L) after Activated by Various Concentration of $Zncl_2$*

Carbonisation of banana peel in the furnace after activated with $ZnCl_2$ produced carbon with bio-sorbent characteristics as shown in Table 1. The analysis results showed that moisture content (5.40-10.70%), volatile matter (5.6-10.40%), ash content (6.7-9.0%), and fixed carbon (73.1-81.80%) still meet the technical activated carbon quality requirements based on SNI 06-3730-1995.

**Table 1**
Characteristics of bio-sorbent from banana peel (*Musa acuminate L*)

| No | Activation Concentration | Activation Time (hours) | Moisture Content (%) | Volatile Matter (%) | Ash (%) | Fixed Carbon (%) |
|---|---|---|---|---|---|---|
| 1 | No-activation | - | 9,36 | 9,36 | 7,70 | 73,58 |
| 2 | $ZnCl_2$ 1 N | 1 | 5,40 | 5,60 | 7,20 | 81,30 |
| 3 | $ZnCl_2$ 1 N | 2 | 6,20 | 5,80 | 6,70 | 75,77 |
| 4 | $ZnCl_2$ 1 N | 3 | 8,00 | 9,23 | 7,00 | 74,90 |
| 5 | $ZnCl_2$ 2 N | 1 | 9,60 | 7,40 | 8,10 | 75,90 |
| 6 | $ZnCl_2$ 2 N | 2 | 9,30 | 8,70 | 6,10 | 73,50 |
| 7 | $ZnCl_2$ 2 N | 3 | 9,50 | 8,40 | 8,60 | 73,10 |
| 8 | $ZnCl_2$ 3 N | 1 | 10,60 | 9,40 | 6,90 | 70,70 |
| 9 | $ZnCl_2$ 3 N | 2 | 10,70 | 10,30 | 8,30 | 69,90 |
| 10 | $ZnCl_2$ 3 N | 3 | 10,70 | 10,40 | 9,00 | 81,80 |
| | Indonesia National Standard | | max 15 | max 25 | max 10 | min 65 |

Furthermore, iodine sorption on bio-sorbent of banana peel (*Musa acuminate L*) before and after activation with $ZnCl_2$ were achieved at 659.88 mg/g and 800 mg/g, respectively. Higher adsorption of iodine solution shows the greater ability of sorbent to absorb certain components of fluid [9-11]. The activation process is intended to enlarge the pores by breaking hydrocarbons or oxidising surface molecules so that the activated carbon structure changes physical and chemical properties; especially its surface area to absorption ability.

Figure 1-3 showed surface analysis results through the FTIR spectrum which indicated that bio-sorbent after activated with $ZnCl_2$ at variation concentration of 1, 2, and 3 N for 1, 2, and 3 hours, respectively showed the presence of C-O vibrations indicated by the presence of absorption bands in the wavelength region of 1080 $cm^{-1}$, functional groups C=C from aliphatic compounds indicated by the presence of absorption bands in the wavelength region of 1640 $cm^{-1}$, and C-H functional groups indicated by the presence of absorption bands in the wavelength region of 2960 $cm^{-1}$. Sorption of the C-H group with strong intensity occurs in the range of 2850 to 2970 $cm^{-1}$ [12-14].

$H_2O$ content influenced the high and low intensity at C-H functional group value, while higher $H_2O$ content occurs the lower of C-H group intensity. The high content of $H_2O$ causes a lower intensity of the C-H group. The surface area of the particles affects the ability of absorbency and the ability of bio-sorbent will be higher when activated chemically at high temperatures. Activators can bind water so that the existing water in bio-sorbent pores is not lost when the carbonization process takes place; then the activator will enter pores and open the closed surface of bio-sorbents. When the heating process takes place, the impurities present in pores become more easily absorbed, and the surface area of the activated carbon becomes bigger and increases its adsorption.

Figure 4(a, b and c) shows the results of bio-sorbent surface morphology analysis. The results showed that there were differences in bio-sorbent morphology between before and after activation with various concentrations of $ZnCl_2$. The bio-sorbent surface which has been activated with $ZnCl_2$ appeared cleaner when compared to the bio-sorbent surface before activation. On the surface of bio-sorbent before activation, the diameter of pore size ranged from 2.011 to 4.652 µm, while the small pores (microspores) were not visible due to the presence of impurities that covered the sorbent surface. Figure 4(d) Shows bio-sorbent surface activated with $ZnCl_2$ which has a smaller pore size diameter (*macrospores*) due to bio-sorbent having undergone emission absorption resulting in the macrospores being covered with exhaust gas impurities from motorised vehicles. $ZnCl_2$ as a chemical activator was able to suppress hydrocarbon impurities and other impurities in the bio-sorbent pores which cause increase the adsorption ability. In the certain mass activators, activators will saturate which results in a decrease in absorbance caused by the destruction of pores on activated carbon which destroys the microspores and mesopores formed [15-18].

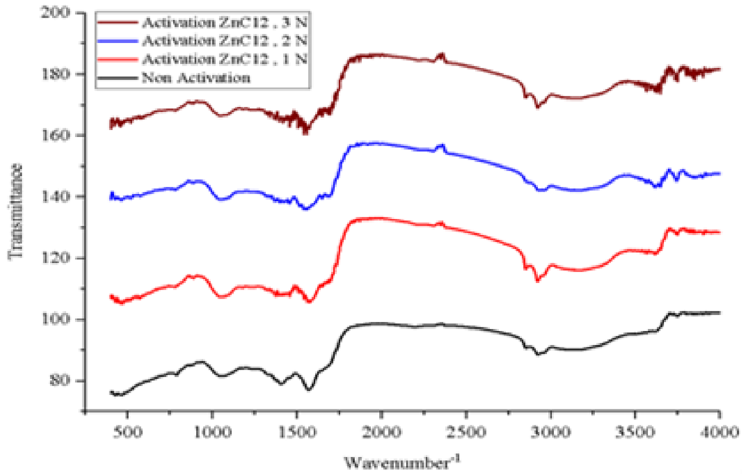


**Fig. 1.** FTIR results of bio-sorbent activated by various concentration of $ZnCl_2$ for one h

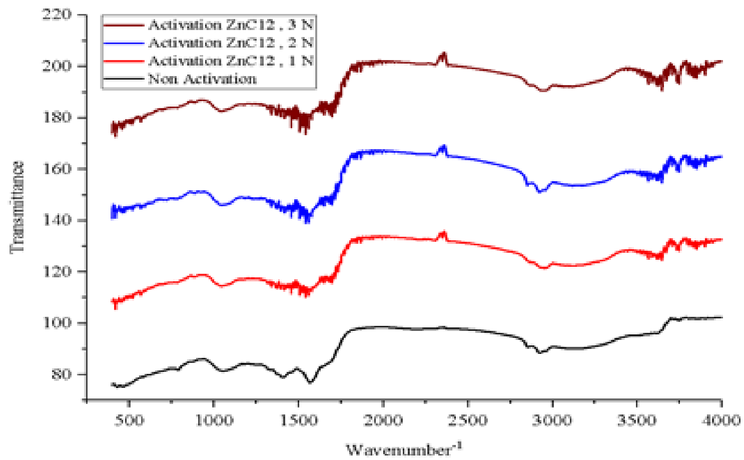


**Fig. 2.** FTIR results of bio-sorbent activated by various concentration of $ZnCl_2$ for two h

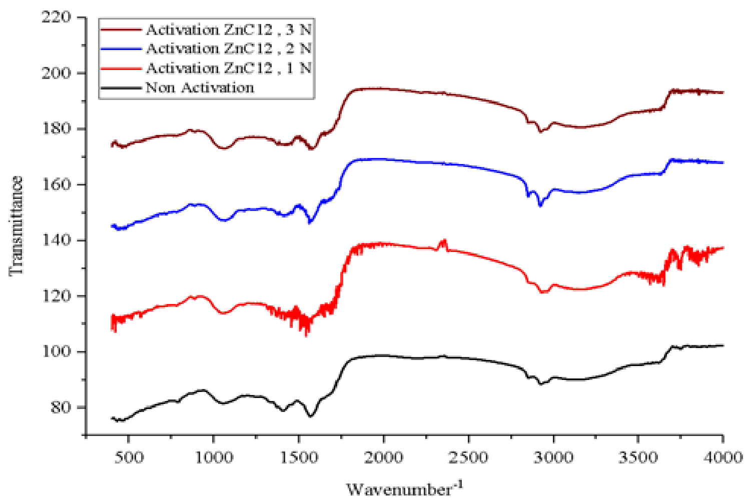


**Fig. 3.** FTIR results of bio-sorbent activated by various concentration of $ZnCl_2$ for three hours

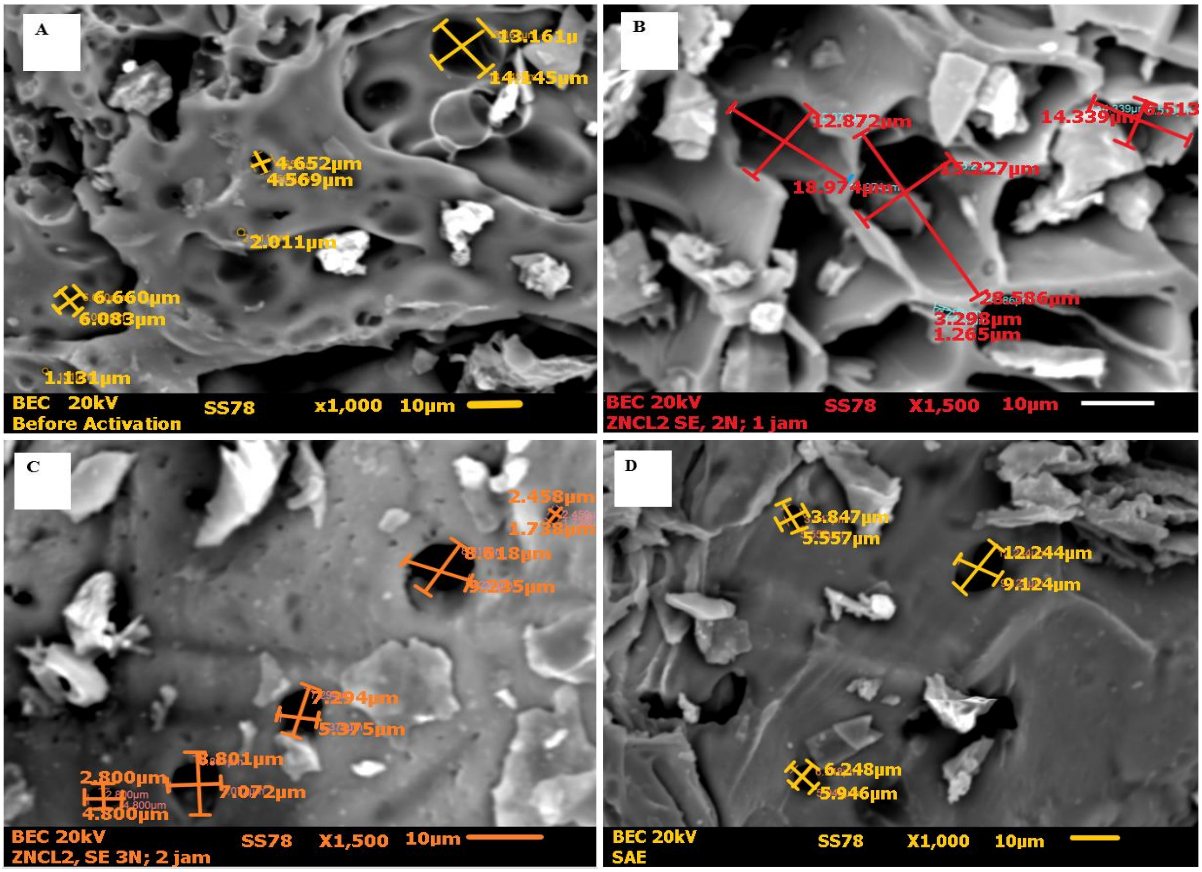


**Fig. 4.** SEM photo of surface morphology of banana peel bio-sorbent. (A) before activation, (B) after activation by 2N $ZnCl_2$, (C) after activation by 3N $ZnCl_2$, (D) after adsorption of Exhaust Gas Emissions of motor Vehicles

### *3.2 Absorption of Exhaust Gas Emissions*

The process of absorption of exhaust emissions was reviewed by measuring CO levels carried out on motorised vehicles (Honda Brand) production of the last five years which were ignited and raised by engine speed at 1900 rpm to 2100 rpm, then hold for 60 seconds, and then returned to the idle condition. Results of exhaust gas emissions before being filled with sorbents under idle conditions with an engine speed of 800 rpm to 1400 rpm are shown in Table 2. CO levels measured in exhaust gases of motor vehicles without bio-sorbents ranged from 13752 – 14567 ppm, while the adsorption of very high emissions was obtained in bio-sorbents activated by $ZnCl_2$ 2N with 3 hour activation time ranging from 6014 – 9686 ppm. These results showed that bio-sorbent of banana peel (*Musa acuminate L*) activated by $ZnCl_2$ could adsorb CO gas emission levels up to 44%.

**Table 2**
Absorption of CO gas emissions on motor vehicles

| Activation Times (hours) | Concentration of CO gas emissions (ppm) | | |
|---|---|---|---|
| | 1N $ZnCl_2$ | 2N $ZnCl_2$ | 3N $ZnCl_2$ |
| 1 | 9674 | 11225 | 12161 |
| 2 | 7472 | 8352 | 11175 |
| 3 | 6191 | 6014 | 9686 |

## 4. Conclusions

Results showed that the characteristics of bio-sorbent from banana peel (*Musa acuminate L*) activated by $ZnCl_2$ still meet the technical activated carbon quality requirements based on SNI 06-3730-1995 with a moisture content of 5.40-10.70%, ash content of 6.10-9.00%, and volatile matter 5.60-10.40%. The FTIR surface test results showed that bio-sorbent occurred an absorption of C-O, C=C, and C-H functional groups. On the bio-sorbent surface of the banana peel which has been activated with $ZnCl_2$ appeared with a larger pore diameter (12.872-28.566 µm) when compared to the bio-sorbent surface before activation. Bio-sorbent of banana peel (*Musa acuminate L*) activated by $ZnCl_2$ can adsorb CO gas emission levels up to 44%.

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