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Modification of Cyclone Separator Based on IOT Arduino Microcontroller with Activated Carbon from Cocoa Shell Waste as A Tool for Controlling Air Pollution

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ABSTRACT
Air pollution is the condition of air that is contaminated by the presence of materials, substances or polluting components. One of the causes of air pollution is the combustion or inseneration process because the residue of the process can be released into the air. Based on ISPU, there are five main pollutants, namely: carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NO_X), surface ozone (O_3), and dust particles (PM_{10}). This study was conducted to reduce the emission of gases. The use of modified cyclone with adsorbent pipe tube from cocoa husk can increase the efficiency of combustion results with adsorption pipe tube modified cyclone. From the results of the study it was found that emissions from incineration can be controlled with APPU in the form of a cyclone. The use of cyclone alone can reduce NO_X and CO levels with a reduction in NO_X emissions to 53% and CO to 96%. Both emission reductions are in line with the quality standards. However, the use of adsorption pipe tubes showed better efficiency and effectiveness.
Keyword: Adsorbent, Cyclone, Emissions, Incineration

ABSTRAK
Pencemaran udara merupakan kondisi udara yang terkontaminasi oleh adanya bahan, zat-zat atau komponen pencemar. Salah satu yang menyebabkan pencemaran udara adalah proses pembakaran atau insenerasi karena zat sisa prosesnya dapat terlepas ke udara. Berdasarkan ISPU, terdapat lima pencemar utama, yaitu: karbon monoksida (CO), sulfur dioksida (SO_2), nitrogen oksida (NOx), ozon permukaan (O_3), dan partikel debu (PM_{10}). Penelitian ini dilakukan untuk mengurangi emisi gas. Penggunaan cyclone termodifikasi dengan tabung pipa adsorben dari kulit kakao dapat meningkatkan efisiensihasil pembakaran dengan cyclone termodifikasi tabung pipa adsorpsi. Dari hasil penelitian didapatkan bahwa emisi dari insenerasi dapat dikendalikan dengan APPU berupa cyclone. Penggunaan cyclone saja dapat mengurangi kadar NO_X dan CO dengan penurunan emisi NO_X menjadi sebesar 53% dan CO sebesasr 96%. Keduanya menunjukkan penurunan emisi hingga sesuai dengan baku mutu yang ditetapkan. Namun, penggunaan tabung pipa adsorpsi menunjukkan efisiensi dan efektivitas yang lebih baik.
Keyword: Adsorben, Siklon, Emisi, Insenerasi

1. Introduction

Air is an important factor for human life because it contains various types of gases needed for the body with different concentration levels. However, currently, there are many activities that cause changes in air concentration, resulting in changes in air quality or air pollution that can interfere with health and the

environment [1]. Air pollution is a condition of air that is contaminated by the presence of materials, substances or other polluting components, causing changes in the composition of air concentrations that can cause disruption of the living system of living things [2]. According to the World Health Organization (WHO), 99% of the world population lives and breathes air that exceeds guideline limits and contains high levels of pollutants [3]. Air is categorised as clean if it meets certain restrictions. The composition of gases contained in the air can be seen in Table 1.1. The criteria for clean air and polluted air can be seen in Table 1.2. Air in nature is never clean without pollutants at all. The presence of contaminants in the air in certain amounts and for a long time will have an impact on life [4].

Table 1.1 Composition of Dry and Clean Air [4]

Component	Formula	Percent Volume	ppm
Nitrogen	N_2	78.08	780.800
Oxygen	O_2	20.95	209.500
Argon	Ar	0.934	9.340
Carbon Monoxide	CO_2	0.0314	314
Neon	Ne	0.00182	18
Helium	He	0.000524	5
Methane	CH_4	0.0002	2
Krypton	Kr	0.000114	1

Tabel 1.2 Clean and polluted air criteria [4]

Parameters	Clean Air	Polluted Air	Unit
Particulates	0.01-0.02	0.07-0.7	mg/m^3
SO_2	0.003-0.02	0.02-2	ppm
CO	< 1	5-200	ppm
NO_2	0.003-0.02	0.02-0.1	ppm
CO_2	310-330	350-700	ppm
Hydrocarbon	< 1	1-20	ppm

One of the causes of air pollution is the combustion or inseneration process because the residual substances of the process can be released into the air. The incineration process can reduce waste by 5-10% by converting solid waste into FABA (Fly Ash and Bottom Ash) and gas emissions such as SO_2, NO_X, CO, and HC. Incineration has a risk of air pollution if it is not controlled and not equipped with air pollution control equipment (APPU) [5]. Based on the Air Pollution Standards Index (ISPU), there are five main pollutants, namely: carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NO_X), surface ozone (O_3), and dust particles (PM_{10}) [1]. The several types of emissions, CO and NO_X are emissions of combustion residual substances that have a negative impact on health and can cause death. NO_X causes environmental impacts such as acid rain, greenhouse effect and causes holes in the ozone layer. Meanwhile, CO gas can inhibit the flow of O_2 by binding to haemogoblin (Hb) and forming COHb. COHb levels in the blood can cause death. Fig. 1.1 shows an illustration of the effects of emissions from combustion without further processing. Therefore, combustion gas emissions are required (APPU) in order to reduce emissions in the air [6].

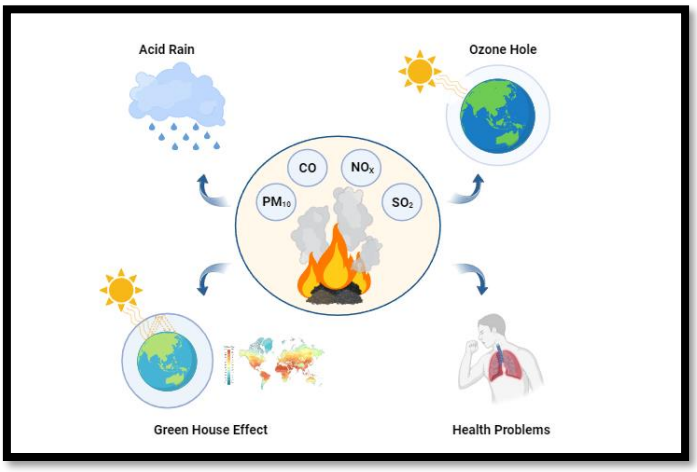

Figure 1.1 Illustration of the effects of emissions from combustion without further treatment

Cyclone separator is an air pollution control device that uses the principle of centrifugal force and gravity created by gas flow to separate particles from gas. Inside the cyclone a vortex occurs which causes particulates and gas to separate, where large density particulates will fall down and small density air will rise up. The efficiency of cyclone collection varies as a function of density, particle size, and cyclone design [7]. Several studies have shown that cyclones are effective in reducing air pollution particulates. Syahrizal et al. (2022) using a cyclone with a particulate flow rate of 0.1 m^3/s obtained a dust separation efficiency of 90% with a particulate size above 50 µm [8]. Meanwhile, the research by Pan et al. (2021) uses cyclones with different sizes and underflow to reduce aerosol particles. The best results were obtained at a diameter of 75 mm and a vortex depth of 95% aerosol particle separation efficiency [9]. Conventional cyclones can reduce air pollution emissions with 85-90% efficiency. However, the disadvantage is the low efficiency on particles with a diameter of less than 10 µm. Therefore, special additional designs are needed to optimise emission efficiency with very small particle sizes [10].

Activated carbon is a carbon compound that has improved its adsorption by carbonisation and activation. Activated carbon is the best adsorbent in adsorption systems. This is because activated carbon has a large surface area and high adsorption power so that its use can be optimised. Activated carbon can be used to remove odour, taste, colour, and other organic contaminants. Activated carbon can also be used as an adsorbent for CO, SO_2, and NO_X gas emissions because it is available in large quantities and has a low price. Chemical adsorbents (in the form of activated carbon/activated charcoal) can theoretically be used to reduce air pollution [11]. With the problem of emissions from the combustion process, in this study, the addition of an adsorption pipe tube is carried out to absorb particulates and gas emissions that still cannot be controlled by the cyclone so as to increase its efficiency and the addition of an IoT (Internet of Things) Arduino Microcontroller through the installation of sensors that can detect the concentration of emissions before and after passing through the modified cyclone.

2. Materials and Methods

In this research, the design of the device is divided into 3 main parts, namely the insenerator, cyclone, and adsorbent pipe with the installation of IoT in the parts before and after the modified cyclone stage. The insenerator section is designed from a box-shaped steel with a size of 50 cm x 40 cm x 30 cm with an outlet that directly leads to the cyclone section. The cyclone geometry is designed based on the design book Air Pollution Control: A design Approach 2nd Edition (Cooper and Alley, 1992) with specifications that can be seen in Table 2.1 and the cycone design can be seen in Fig. 2.1 The cyclone is made of galvanised iron sheet metal with a thickness of 1 mm. The cyclone outlet leads directly to the adsorbent pipe inlet with a length of 1 m made of galvanised iron with a thickness of 1 mm made vertically.

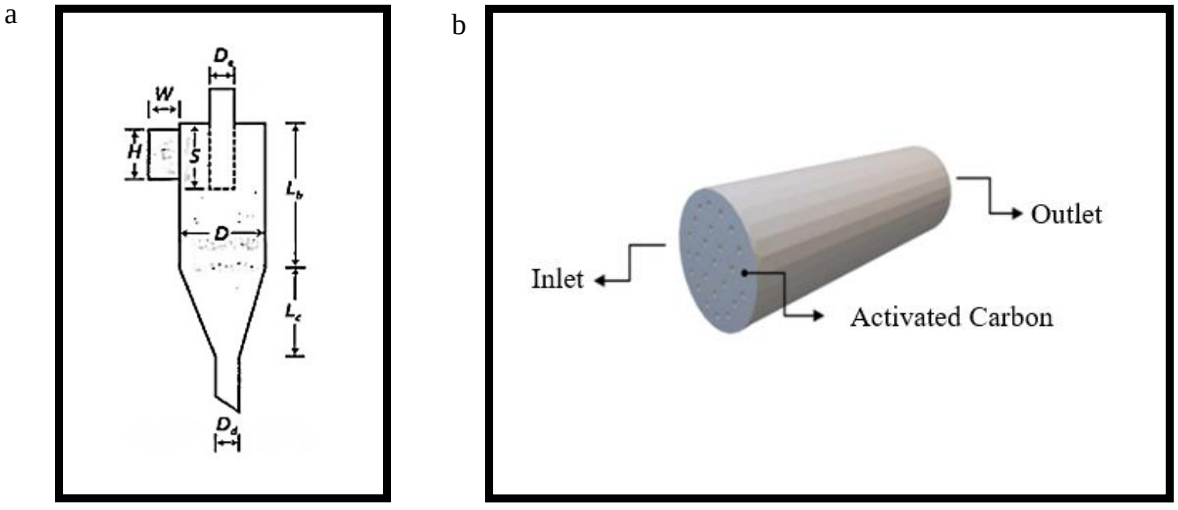

Figure 2.1 (a) Design of Cyclone (b) Design of Adsorbent Pipe Tube

Figure 2.2 Modified Cyclone Prototype

Table 2.1 Cyclone Dimensions [12]

Cyclone Section	Dimension	
Body Diameter	D/D	1
Inlet Height	H/D	0.5
Inlet Width	W/D	0.2
Gas Outlet Diameter	D_0/D	05
Vortex Finder Length	S/D	0.5
Body Length	Lb/D	1.5
Cone Length	Lc/D	2.5
Particulate Output Diameter	Dd/D	0.375

The preparation of activated carbon starts from the preparation of cocoa pods (*Theobroma cacao L.*) waste samples as much as 5 kilograms of cocoa pods that have been collected are washed with aquadest, then dried in the sun for 8 hours as a dehydration stage. The dried cocoa pods were taken randomly and put into a large mortar and pounded until the size became smaller. After pounding, the cocoa pods were carbonised using an oven at 500°C for 1 hour until they became charcoal. The charcoal was then cooled, mashed, and sieved using a 40 mesh sieve. Next, the activation stage was carried out, as much as 50 grams of charcoal was put into a beaker glass 500 mL (Iwaki), then 100 mL of 10% (b/v) $ZnCl_2$ solution was added, and waited for 24 hours. Then the residue was washed with distilled water until the pH was neutral. When the pH is neutral, put the residue into an oven at 100^{o}C for 2 hours.

3. Results and Discussion

The modified cyclone testing process is carried out by connecting three main parts, namely the incinerator, cyclone, and adsorbent pipe tube. Data analysis was carried out by calculating the concentration of exhaust gas from the incinerator, the concentration of cyclone output gas without adsorbent pipe tube, and the concentration of modified cyclone output gas with adsorbent pipe tube. The data obtained is compared with the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number: P.70/Menlhk/Setjen/Kum.1/8/2016 concerning Quality Standards for Business Emissions and/or Thermal Waste Processing Activities which can be seen in Table 3.1 Based on the design that has been made, there are two sensors that will be installed on the cyclone, namely at the insenerator outlet, the modified cyclone outlet. The test data is taken from the sensor readings of the pollutant parameters to be identified, namely SO_2, NO_X, and CO gas emissions.

Table 3.1 Air Quality Standard for Emissions of Thermal Waste Processing Businesses and Activities [13]

No	Parameters	Unit	Maximum Limit
1	Total Particulates	mg/Nm^3	120
2	Sulfur Dioxide (SO_2)	mg/Nm^3	210
3	Carbon Monoxide (CO)	mg/Nm^3	625
4	Nitric Oxide (NO_X)	mg/Nm^3	470

The incineration process is carried out by including waste obtained from the surrounding environment both organic and inorganic waste. Incineration is a waste management technique through processing that involves high temperatures. The incineration process is influenced by thermal factors. The result of the incineration process is to convert polymer and non-polymer waste into ash phase, gas phase, and also thermal [14]. The incinerator outlet is detected by the sensor before entering the cyclone stage. This outlet is the inlet of the cyclone for the process of separating emissions from the inseneration. At the outlet of the cyclone, a sensor is also installed to determine the final level of emissions after the separation process with the cyclone. The inlet and outlet results and the efficiency of the cyclone are shown in Table 3.2.

Table 3.2 The Inlet and Outlet Results and The Efficiency of The Cyclone

No	Parameters	Inlet (mg/Nm^3)	Outlet (mg/Nm^3)	Efficiency (%)
1	SO_2	0	0	-
2	NO_X	130.82	82.988	37
3	CO	2,505.555	222.931	91

From Table 3.2 it can be seen that the sensor only detects NO_X and CO levels. At the cyclone inlet, the NO_X emission level is 130.2 mg/Nm^3 and CO is 2.505.555. At the outlet of the cyclone, the NO_X level was 82.988 and CO was 222.311. The efficiency of NO_X reduction was found to be 37% and for CO was 91%. From these data, the cyclone tool used can reduce pollution emission levels well and has met quality standards. Furthermore, experiments were carried out with the addition of adsorbent pipe tubes at the outlet of the cyclone. At the outlet of the adsorbent pipe tube is also equipped with a sensor to see the emission levels. The inlet and outlet results and efficiency of the modified cyclone with adsorbent pipe tubes are shown in Table 3.3.

Table 3.3 The Inlet and Outlet Results and Efficiency of The Modified Cyclone with Adsorbent Pipe Tubes

No	Parameters	Inlet (mg/Nm^3)	Outlet (mg/Nm^3)	Efficiency (%)
1	SO_2	0	0	-
2	NO_X	63.755	29.477	53
3	CO	2,000.003	81.35	96

From Table 3.3 it can be seen that at the inlet cyclone, the NO_X emission level is 63.755 mg/Nm^3 and CO is 2.000.003. At the outlet of the cyclone, the NO_X level is 29.447 and CO is 81.35. The efficiency of NO_X reduction was found to be 53% and for CO was 96%. The use of adsorbent pipe tubes provides an increase in efficiency in the cyclone. The decrease in emission levels occurred because the emission gases were absorbed by the pores of the cocoa husk adsorbent. Adsorbents that have a large pore surface area can absorb gas. Gas absorption occurs by diffusion at the surface of the pores. Activated carbon has pores up to < 2 nm in size and has a large surface area so that the gas absorption capacity will be large. Pores that can no longer absorb gas will become saturated and the gas cannot diffuse so that it escapes [15]. This causes a small amount of gas to escape.

4. Conclusion

Emissions from combustion can be controlled with an APPU in the form of a cyclone. The use of cyclone alone can reduce NO_X levels with an efficiency of 37% and CO by 91%. For the use of a cyclone modified with an adsorbent pipe tube from cocoa husk can increase the efficiency of reducing NO_X emissions to 53% and CO as much as 96%. Both experiments conducted with the adsorbent pipe tube modified cyclone and the cyclone alone showed a decrease in emissions to meet the specified quality standards. However, the use of adsorbent pipe tube showed better efficiency and effectiveness.

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