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The Effectiveness of Coconut Fiber Air Filtration in Reducing PM $_{2.5}$ and PM $_{10}$ in the Home Industry of Sago Craftsmen in Jaya Village, Tidore Islands City

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A B S T R A C T

Particulate Matter (PM) is a dangerous pollutant of various sizes that can be detrimental to health, through penetration of the respiratory tract and entering the bloodstream. The sago industry (home industry scale) located in residential areas causes health problems, such as shortness of breath, dizziness and headaches. The study aims to analyze the effectiveness of air filtration made from coconut fiber to reduce particulates in the air ($PM_{2.5}$ and PM_{10}). The study used a one group pre-post test design, conducted in seven sago industries (home industries) in Jaya Village, Tidore Islands City. Data processing used Bivariate analysis, which was carried out to see wood dust before and after treatment. Data analysis used Paired T-Test to assess differences in PM levels before and after treatment. The results showed a difference in PM $_{2.5}$ levels before and after treatment (P= 0.0001). Similarly, PM_{10} parameters also showed a significant difference (P = 0.007). Based on these results, coconut fiber air filters are effective in reducing PM $_{2.5}$ and PM_{10} concentrations.

Particulate Matter (PM) merupakan polutan berbahaya dengan berbagai ukuran yang dapat merugikan kesehatan, melalui penetrasi saluran pernapasan dan masuk dalam aliran darah. Industri sagu (skala home industry) yang berada di pemukiman menyebabkan gangguan kesehetan, seperti sesak napas, pusing hingga nyeri kepala. Penelitian bertujuan menganalisis efektifitas filtrasi udara berbahan sabut kelapa untuk menurunkan partikulat di udara ($PM_{2.5}$ dan PM_{10}). Penelitian menggunakan rancangan one group pre-post test design, dilaksanakan di tujuh industry sagu (home industry) Kelurahan Jaya, Kota Tidore Kepulauan. Pengolahan data menggunakan analisis Bivariat yaitu dilakukan untuk melihat debu kayu sebelum dan sesudah perlakuan. Analisis data menggunakan Paired T-Test untuk menilai perbedaan kadar PM sebelum dan sesudah perlakuan. Hasil penelitian menunjukan perbedaan kadar $PM_{2.5}$ antara sebelum dan seudah perlakuan (P= 0,0001). Demikian pula untuk parameter PM_{10}, juga menunjukkan perbedaan yang signifikan (P= 0,007). Berdasarkan hasil penelitian ini maka filter udara berbahan sabut kelapa efektif dalam menurunkan kosentrasi $PM_{2,5}$ dan PM_{10}.

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1. Introduction

Air quality is affected by the presence of pollutants originating from industrial activities such as *the home industry* of sago production, most of which will be in the air and affect air quality, one of which is particulate matter (PM). Dust particles of various sizes during the smoking process will fly in the air or fall to the floor due to the earth's gravity.

The Environmental Protection Agency (EPA) classifies dust particles based on their size into 2 categories, namely particulate matter=10 micrometers and dust particles=2.5 micrometers (US EPA, 2024) . If inhaled into the body, they can penetrate the lower respiratory tract and can pass through the bloodstream (Indriani et al., 2018) . In the body, particulates can settle into the respiratory tract through several physical mechanisms such as sedimentation, impaction, diffusion, interception, and electronic precipitation (Hastiti, 2012) .

According to data on disease cases collected by the Ministry of Health through the 2018 Basic Health Research, as part of a basic health study, the category of diseases caused by environmental media (air) shows that cases of acute respiratory infections (ARI) amounted to 9.3%. The short-term effects include an increased risk of death due to cardiovascular and respiratory disorders. Every 10µg/m3 increase in PM $_{10}$ indoors increases cardiovascular deaths by 0.36% and respiratory deaths by 0.42% (Ministry of Health, 2018) .

Data on disease cases collected by the Ministry of Health through the 2018 Basic Health Research as part of a basic health study on the category of diseases caused by environmental media (air), cases of acute respiratory infections (ARI) amounted to 9.3 %. The short-term effects include an increased risk of death due to cardiovascular and respiratory disorders. Every 10µg/m3 increase in PM_{10} in the home will increase deaths due to cardiovascular by 0.36% and deaths due to respiratory disorders by 0.42%.

Cigarette filters made from coconut fiber containing natural cellulose as a substitute for cellulose acetate. The research showed that the emission factor of ultrafine particles becomes lower when the density of the coconut fiber filter is increased. Several studies have stated that natural polymers with sugar chain structures can be found in various types of plants with varying levels. One of them is in coconut fiber which contains 43.44% natural cellulose (Faslah et al., 2017) . This study aims to analyze the effectiveness of air filtration made from coconut fiber in reducing air pollutant particles ($PM_{2.5}$ and PM_{10}) in the home industry of sago craftsmen in Jaya Village, Tidore Islands City.

2. Methods

The research design used is pre-experimental research with one group pre-post test design method which aims to analyze causal relationships by involving one group of subjects, so that this study analyzes the effectiveness of a simple filtering system using coconut fiber for $PM_{2.5}$ and PM_{10} particulate emissions. The sample size is 7 Sago processing home industries taken using simple random sampling techniques. This analysis uses *Paired T-Test*.

PM concentrations produced by the sago processing home industry were measured before and after treatment, or after using a simple filtration device (Figure 1) designed to reduce PM concentrations in the air. PM was measured using *EVM-Environmental*. The simple filtration device uses dried coconut fibers to form fibers. The following is the design of the coconut fiber filtration tool used in this study:

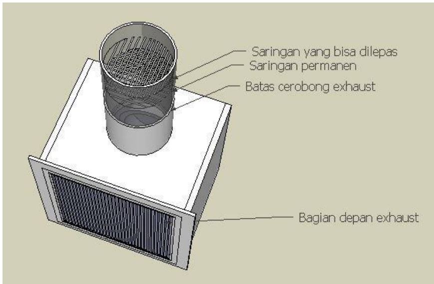

Figure 1. Air Filtration

3. Results

This research is pre-experimental with a one group pre-post test design method. Research data collection uses air pollutant measurements in the form of $PM_{2.5}$ and PM_{10}, so that the data obtained is quantitative. The study began with a pretest of Particulate Matter measurements, then provided treatment using appropriate technology tools, namely coconut fiber filtration, after which a posttest of Particulate Matter measurements was conducted.

Table 1. Frequency Distribution of PM $_{2.5}$ Pretest and Posttest Measurements

Criteria	Frequency			
	Pretest		Posttest	
	n	%	n	%
Meet NAB	3	42.9	6	85.8
Not Meeting NAB	4	57.1	1	14.2

Based on Table 1, it can be interpreted that $PM_{2.5}$ measurements before (pretest) treatment that exceeded the Threshold Limit Value (TLV) or did not meet the standard were 57.1% of sago artisan home industries, and those that met the TLV or were in the safe category were 42.9%.

Meanwhile, the results of $PM_{2.5}$ measurements after being given treatment in the form of a coconut fiber filtration device that met the TLV were 85.8% and did not meet the TLV were 14.2%.

Table 2. Frequency of PM_{10} Pretest and Posttest

Criteria	Frequency			
	Pretest		Posttest	
	n	%	n	%
Meet NAB	2	28.6	6	85.8
Not Meeting NAB	5	71.4	1	14.2

Table 2 shows that the PM_{10} measurements before (pretest) treatment that did not meet the Threshold Limit Value (TLV) were 71.4% in the sago artisan home industry, and those that met the TLV or were in the safe category were 28.6%. Meanwhile, the PM_{10} measurements after treatment in the form of a coconut fiber filtration device that met the TLV were 85.8% and those that did not meet the TLV were 14.2%.

The results of the data normality test in this study using the *Kolmogorov Smirnov test* presented in table 3 :

Table 3. Results of Data Normality Test

Variables	P	Information
$PM_{2.5}$	0.983	Normal
PM_{10}	0.824	Normal

Table 3 is the result of the normality test using *the Kolmogorov Smirnov method* using the computerized program/SPSS 25.0 (attached) on the variables $PM_{2.5}$ and PM_{10}. In the table, the significance value for the $PM_{2.5}$ variable is P= 0.983 and variable PM_{10}= 0.824. Both variables follow a normal distribution/normally distributed because the significance value is greater than alpha 5% (0.05). From these results, the data analysis used is the *Paired Samples T test.*

Table 4. *Paired Samples T-Test* in Reducing $PM_{2.5}$

Variables	Average	Correlation	p-value
Before $PM_{2.5}$	2602.87	1,000	0,000
After $PM_{2.5}$	1140.73		
Before PM_{10}	400.47	0.968	0.007
After PM_{10}	141.93		

Based on Table 4, it shows that the calculation uses *Paired Samples T Test,* the p-value is less than 0.05, so it means that there is a significant difference between before and after, which means that coconut fiber-based air filtration is effective in reducing $PM_{2.5}$ in the Sago Craftsman Home Industry. The correlation value between the two variables is 1.000, meaning a strong and positive relationship.

Table 4 interprets that the significance value (P= 0.007) is smaller than 0.05, meaning that there is a difference between the results before and after the measurement for the PM_{10} variable. So, it can be concluded that coconut fiber-based air filtration is effective in reducing PM_{10} in the Sago Craftsman Home Industry. The correlation value between the two variables is 0.968, meaning a strong and positive relationship.

4. Discussion

The research area is located in Jaya Village, Tidore Islands City, a mountainous region. One of the local people's livelihoods is making sago from cassava. Sago production facilities on a household scale are known as home industries. Various types of sago flavors are produced, ranging from original, chocolate, and others. The sago production facility is usually a building measuring approximately 3 x 4 meters with bamboo or cement walls and a tiled roof without a chimney. Some home industries are integrated with the house. Sago production activities are carried out in the morning, starting at 7:00 a.m. WIT until finished, depending on the amount of dough. The cassava processed by sago craftsmen comes from local farmers.

The sago-baking process begins with preparing sun-dried coconut shells and firewood, preparing the sago dough, and preparing the tools/fireplace for making the sago. The primary fuels used in the sago-baking process are coconut shells and firewood. The sago artisan sits approximately 0.5 meters from the stove.

Based on interviews with sago home industry owner, the time it takes to make sago depends on the amount of sago dough. The smoke produced by burning coconut shells and firewood provides heat to the sago dough. Furthermore, the resulting combustion produces a significant amount of smoke during the cooking process.

The research team measured $PM_{2.5}$ and PM_{10} in the field based on a time contract with the sago *home industry owner*. Measurements were taken at three points in each fish smoking house.

$PM_{2.5}$ are particles with a size of <2.5 micrometers with the main sources being combustion, cigarette smoke, cooking with firewood, and agricultural activities (US EPA, 2024) . The regulation used in measuring $PM_{2.5}$ is Permenkes No. 1077 of 2011 concerning indoor air health, the type of $PM_{2.5}$ parameter has a NAB for the unsafe category of >3 μg/m^3.

$PM_{2.5}$ is a respirable dust that can persist from the terminal bronchioles to the alveoli, making it one of the most dangerous types of dust. Health effects from this particulate matter include premature death in people with heart and lung disease, heart attacks, irregular heartbeats, asthma, decreased lung function, and increased respiratory symptoms such as airway irritation, coughing, and difficulty breathing. Therefore, proper treatment or prevention at the source is essential (Pratiwi et al., 2023) .

The results of $PM_{2.5}$ concentration measurements before (pretest) being given treatment in a fish smoking place 100% exceeded the Threshold Limit Value (NAB) stipulated by the Minister of Health Regulation No. 1077 of 2011 concerning guidelines for indoor air health (35 μg/m^3) (KEMENKES, 2011) . While the results of $PM_{2.5}$ measurements after being given treatment in the form of a coconut fiber filtration device that meets the NAB is 40% and does not meet the NAB is 60%. So, it can be concluded that $PM_{2.5}$ during the pretest is higher than the posttest. This means that there is a decrease in the number of home industries used as places for measuring $PM_{2.5}$ parameters.

Differences in $PM_{2.5}$ concentrations in each *home industry* can be caused by wind direction, temperature, and humidity. The tendency for wind directions varies, namely west, east, and north. Wind direction can affect the movement of smoke, thus affecting the concentration of $PM_{2.5}$ measured by the $PM_{2.5}$ device. Wind direction is the movement of air that can cause the spread of air pollution, so that the level of a pollutant at a certain distance from the source has a different level (Avrianto, 2011) . The concentration of pollutants in the air can be affected by wind, humidity, and air temperature; the higher the wind speed, the lower the concentration of pollutants in the air (Istantinova et al., 2013).

A high air temperature of 33.1°C can increase the concentration of particles in the air. The high temperature of the fish smoking environment can be influenced by the continuous burning of coconut shells (Qian, Z, He, Q, Molin, H, Kong, L, Bentley, C, Liu, W, 2008) . Air humidity can affect the concentration of dust particles in the air (Pramitha & Putri, 2012) .

PM_{10} is aerodynamic particulate matter with a diameter of less than 10 micrometers resulting from human activities, mostly from motor vehicles and industry (Haq, *et al.,* 2002), which produces high particulate and hydrocarbon emissions. One type of work that can pose a risk of decreased lung function due to PM_{10} is sago craftsmen in the sago home industry.

The results of the study showed that the pretest PM_{10} that met the NAB was 60% and did not meet the NAB was 40%. While for the posttest on the measurement of PM_{10} that met the NAB was 80% and did not meet the NAB 20% of sago home industries. This means that the number of sago home industries decreased from before and after being given treatment, namely coconut fiber filtration tools, evidenced by PM_{10} in the criteria of not meeting the NAB or unsafe category by 40% decreased to 10%. The regulation used in measuring $PM_{2.5}$ is Permenkes No. 1077 of 2011 concerning indoor air sanitation, the type of PM_{10} parameter has a NAB for the unsafe category is >70 μg/m^3 (KEMENKES, 2011) .

high concentration of PM_{10} in *the home industry* aligns with the statement that an estimated 80% of the total global population is exposed to indoor air particulates, especially in developing countries. During cooking, when women and young children spend time in the kitchen and near the fireplace, some measured PM_{10} levels are quite high, reaching 30,000 µg/m or more (Arba & Mustafa, 2024) . This can support this research because most sago burning areas are adjacent to or integrated with houses. In addition, the fuel used is coconut shells and firewood.

In general, based on fuel type, PM_{10} concentrations in kitchens using wood fuel are much higher than those using kerosene, both during cooking and non-cooking conditions. This is because burning with kerosene produces higher combustion efficiency, resulting in less PM_{10}.

This study uses air filtration as an appropriate technology (TTG) tool that was tested on air pollutants in the form of $PM_{2.5}$ and PM_{10} parameters in a sago home industry. Air filtration is an air filtering used in air health studies with the aim of minimizing air pollution caused by industrial activities and transportation. Therefore, in view of this, researchers conducted research related to air pollution caused by burning from sago production using local materials, namely coconut fiber. The purpose of this study was to see the effectiveness of the coconut fiber filtering system on $PM_{2.5}$ and PM_{10}.

Analysis of $PM_{2.5}$ measurement results using *Paired Samples T Test,* the *p value* is 0.000 which is less than the critical limit of the study (<0.05), so it can be concluded that the hypothesis is to accept H1. This means that there is a significant difference between $PM_{2.5}$ measurements before and after which means that a simple filtration tool made from coconut fiber is effective in reducing $PM_{2.5}$ in the sago home industry. And the results of the PM_{10} analysis found that the significance value or *p value*= 0.007 is smaller than <0.05, meaning that there is a difference between the results before and after the measurement for the *Particulate Matter* 10 variable. So, it can be concluded that a simple filtration tool made from coconut fiber is effective in reducing PM_{10} in the sago home industry.

This is due to the content of coconut fiber which generally has a high biomass. Plants that have a high biomass have a high oxygen supply, resulting in a decrease in the percentage of PM (10). The results of CO measurements at point 1 carried out at the traffic light flyover before filtering were 60 ppm and decreased by 40 ppm after passing through the banana stem and *zeolite filter media* to 20 ppm. This shows that coconut fiber alone is able to filter gas parameters, let alone *particulate matter* produced by combustion (MU`TAMIRAH & Sunu, 2019) .

Coconut fiber has potential as a biomass filter, bioabsorbent, and heavy metal bioaccumulator. This is due to its high percentage of cell wall material, which acts as a source of metal binding and is also a source of biomass. It also contains high cellulose, a fibrous compound with high tensile strength, making it possible to use it as a biomass filter capable of absorbing $PM_{2.5}$ and PM_{10}. Furthermore, coconut fiber is abundantly available, inexpensive, and has little economic value (Zhang et al., 2022) .

Coconut fiber has the potential to reduce particulate matter, where its use as a filter medium can reduce $PM_{2.5}$ and PM_{10} parameters in the sago production process. This is due to the influence of the biological processes of coconut fiber and the high percentage of organic matter and biomass in banana stems. The direct (continuous) use of banana stem filter media over a long period of time can provide an alternative air quality technology using filter media made from natural or organic materials that is easy and inexpensive. It is hoped that the use of coconut fiber will be able to neutralize particulate matter in the sago combustion process. The results of this research are in the form of an appropriate technology tool made from coconut fiber. Smoke exposure is one of the causes of health problems such as acute respiratory infections (ARI) in children, chronic obstructive pulmonary disease (COPD), asthma, and lung cancer (Azhari et al., 2021). The source of smoke comes from human activities which can be in the form of biomass burning (household wood burning, forest fires and others) and also includes cigarette smoke (Reategui-Inga, Manuel, José Kalión Guerra Lu, Wilfredo Alva Valdiviezo, Cecilia Antony Ninahuanca Tocas, 2024).

5. Conclusions

Based on the results obtained from this study, it can be concluded that air filtration devices made from coconut fiber are effective in reducing air pollutants in the form of $PM_{2.5}$ and PM_{10} concentrations.

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