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(Research Article)

Comprehensive assessment of environmental impacts: exhaust gas emissions from goods transport trucks in Manokwari regency and effective mitigation strategies

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Abstract

This study aimed to analyze the concentration of %HSU (Heavy Smoke Unit) in the exhaust emissions of freight trucks in Manokwari Regency. It employed a quantitative research approach and utilized incidental sampling to select a total of 30 vehicles as samples. To examine the relationship between exhaust emissions and vehicle characteristics, linear regression analysis was employed. Out of the 14 vehicles (46.67%) that failed the emission test, only 2 (14.29%) were produced before 2010, while the production of the remaining 12 (85.76%) was after 2010. Simultaneously, Cylinder Capacity (X_1), Trip Length (X_2), Vehicle Age (X_3), and Vehicle Maintenance (X_4) influenced the %HSU value (Y). This was indicated by the very small p-value (0.000), where the mean differences between the groups were highly statistically significant. The results showed that the independent variables were mutually related and collectively have a significant impact on the %HSU value.

Keywords: Cylinder capacity; Exhaust emissions; Maintenance; Trucks; % HSU

1. Introduction

The transportation industry plays a crucial role in driving overall economic growth, and its resurgence directly reflects the ongoing economic development expansion. However, it is widely acknowledged that this sector has the potential to significantly impact the environment, specifically through air pollution. According to the Ministry of Environment, cities have witnessed a decline in air quality, with the transportation sector being responsible for 90% of motor vehicle-related air pollution. To reduce the amount of air pollution caused by the use of fossil fuels, the Indonesian government has issued Law Number 22 of 2009 concerning Traffic and Road Transportation for Motor Vehicle Users.

The combustion process generated by motor vehicles contains harmful chemical gases including CO, H, C, NO, NOX, and Pb. These parameters are highly dangerous and, at certain concentrations, can cause death. Therefore, the increase in the number of vehicles also has negative impacts on living organisms, regardless of their benefits [1]. One of the types of vehicles that contribute the most to air pollution is trucks. Despite their lower numbers in comparison to other types of vehicles, trucks emit a significant amount of exhaust emissions during the combustion process. Furthermore, exhaust emissions may contain chemicals that pose a severe threat to human health when their concentrations in the air exceed the threshold limit.

Trucks, as a commonly used mode of transportation for goods distribution, provide convenience for people. However, with the continuously increasing demand, they have serious impacts on the surrounding environment, such as noise pollution, traffic congestion, and air pollution from exhaust emissions.

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Following its designation as the capital of the province, Manokwari Regency has witnessed a steady population growth, accompanied by a rise in the number of motor vehicles. Consequently, this surge has contributed to an escalation in air pollution levels, posing significant hazards and negatively impacting the overall environmental quality. Furthemore, over the years, the number of motor vehicles in Manokwari Regency has consistently risen. Dominant types include motorcycles, minibusses, pickups, and trucks. For instance, between 2018 and 2020, the number of motorcycles doubled from 28,359 units to 46,618 units. The same upward trend is observed for minibusses, increasing from 4,760 units to 8,183 units. Trucks have also seen an increase, with their numbers rising from 1,321 units in 2018 to 1,793 units in 2020 [2].

The increase in the number of motor vehicles, specifically trucks fueled by diesel does not seem to be accompanied by vehicle fitness. This is due to the prolonged use or age of the vehicles and lack of maintenance, resulting in excessive emissions. Therefore, it is necessary to assess the level of air pollution by analyzing the emissions of motor vehicles used in the transportation of goods on land. This analysis regulates traffic monitoring on roads to control and reduce emissions from transport vehicles.

2. Material and Methods

The study was conducted at the Technical Implementation Unit for Vehicle Testing of the Transportation Office in Manokwari Regency, located in Arfai, for a duration of two months from September to October 2022. It adopted a quantitative approach, employing measurements of exhaust gas emissions to conduct the emission tests. The sampling procedure involved incidental selection, resulting in a total of 30 vehicle units being included in the study. To ensure accuracy and standardization, the measurement of exhaust gas emissions adhered to the guidelines outlined in Minister of Environment Regulation No. 05 of 2006 and SNI 19-7118.2-2005. The measured variables included the emission test results (%HSU) and vehicle characteristics such as cylinder capacity, trip length, vehicle age, and maintenance. To determine the pollution level, the emission data was compared to the threshold values set by Minister of Environment Regulation No. 05 of 2006. Furthermore, multiple linear regression analysis was used to determine the influence of vehicle characteristics on the %HSU emission content.

3. Result and Discussion

In this study, 4 truck manufacturers were found, namely Mitsubishi, Hino, Toyota, and Isuzu. Mitsubishi trucks dominated the freight market in Manokwari, accounting for 70% of the sample. Hino accounted for 23.33% of the trucks, while Isuzu and Toyota only represented 3.33% each. Based on their cylinder capacity, the freight trucks were categorized into three groups, namely trucks with a cylinder capacity of < 300 CC, 3000 - 5000 CC, and > 5000 CC. Furthermore, Mitsubishi trucks had the highest number of units in the < 3000 CC and 3000 - 5000 CC categories, with 9 and 12 units, respectively. Hino trucks had the highest number of units in the 3000 - 5000 CC category, with 7 units, while Isuzu and Toyota had 1 unit each in the < 3000 CC and 3000 - 5000 CC categories. Meanwhile, the > 5000 CC category had no truck brand.

Based on the trip length, the majority of the trucks were categorized in the range of 184,198 - 330,197 KM (11 vehicles), followed by the categories of 38,197 - 184,197 KM, 330,198 - 476,198 KM, 622,200 - 768,199 KM, and 768,200 - 914,200 KM, each consisting of 4 vehicles. Regarding the age distribution of the vehicles, the majority of the sampled vehicles fell within the 4-7, 8-12, and 13-16 year categories, with 14, 7, and 4 vehicles, respectively. Most of the analyzed vehicles were relatively new or considered to be in their early years of service. As for maintenance, 40%, 6.67% and 53.33% of the respondents reported infrequent, occasional, and frequent maintenance.

Emission measurement of truck exhaust gases was conducted through opacity testing (%HSU). Opacity testing for diesel vehicles was performed to measure the concentration of solid particles emitted by diesel-powered vehicles. The test involved measuring the amount of solid particles present in the vehicle's exhaust gas while the engine was running at a stable speed. The pollutants emitted by diesel vehicles were highly complex and consist of a mixture of organic and inorganic substances, commonly referred to as *Particulate Matter* (PM). This substance can reach the respiratory system and lungs when inhaled, causing disruptions and leading to the formation of black spots [3]. The emission test results indicate that the opacity indicator (%HSU) has an average value of 49.03%, with a relatively high standard deviation of 18.451%. Furthermore, the range of values obtained is quite large, at 80%, with the lowest and highest value recorded from the samples being 15% and 95%, as shown in Table 1.

Table 1 Opacity Concentration (% HSU) of Truck Vehicle Emissions

Indicator	N	Range	Min	Max	Mean	Std. Dev
%HSU	30	80	15	95	49,03	18,451

The Minister of Environment on behalf of the Government established emission limits for vehicles in Regulation No. 05 of 2006. Specifically, motor vehicles powered by compression ignition or diesel engines were categorized based on *Gross Vehicle Weight* (GVW) into two groups: vehicles with a GVW < 3.5 tons and GVW > 3.5 tons. Furthermore, each GVW category was differentiated based on the year of manufacture, namely before 2010 (<2010) and after 2010 (>2010). For vehicles with a GVW of < 3.5 tons and > 3.5 tons manufactured before 2010 (<2010), the opacity threshold (%HSU) was set at 70%. Vehicles with GVW < 3.5 tons manufactured after 2010 (>2010) had a threshold of 40%, while GVW > 3.5 tons manufactured after 2010 (>2010) had a threshold of 50%.

The results of exhaust emissions from truck vehicles on air pollution based on the weight classification of vehicles in Manokwari Regency are presented in Table 2 below.

Table 2 Results of Exhaust Emissions from Truck Vehicles on Air Pollution According to the GVW Classification in Manokwari Regency

	Emission Test Results	Classification		Total
		< 3,5 ton	> 3,5 ton	
1	Did Not Pass Emission Test	7	7	14
2	Pass Emission Test	4	12	16
Total		11	19	30

From the data table above, 11 vehicles (35.67%) did not pass the emission test (7 vehicles with GVW < 3.5 tons and 4 vehicles with GVW > 3.5 tons), while 19 (63.33%) passed the emission test (4 vehicles with GVW < 3.5 tons and 12 vehicles with GVW > 3.5 tons).

The results explained that vehicles with GVW > 3.5 tons have a higher percentage of passing the emission test. This was because vehicles with higher GVW had larger and more complex engines compared to those with smaller GVW. The engines were equipped with advanced technologies to control the emitted exhaust gases. Furthermore, vehicles with GVW > 3.5 tons were often used for business purposes, leading to regular maintenance and repairs to ensure optimal engine performance and compliance with emission standards. The government imposed stricter emission standards for vehicles with GVW > 3.5 tons to produce higher emissions compared to those with GVW < 3.5 tons. Therefore, manufacturers producing vehicles with GVW > 3.5 tons often focus on developing better emission control technologies to ensure compliance with the established standards.

Similar results were also obtained when comparing the results with the manufacturing year as shown in Table 3.

Table 3 Results of Exhaust Emissions from Trucks Against Air Pollution by Year of Manufacture in Manokwari Regency

No	Emission Test Results	Production year		Total
		< 2010	> 2010	
1	Did Not Pass Emission Test	2	12	14
2	Pass Emission Test	6	10	16
Total		8	22	30

Based on the results, out of 14 vehicles (46.67%) that failed the emission test, only 2 (14.29%) were produced before 2010, while the remaining 12 (85.71%) were produced after 2010. On the other hand, out of 16 vehicles (53.33%) that passed the emission test, only 6 (37.5%) were produced before 2010, while the other 10 (62.5%) were produced after 2010.

Vehicles produced before 2010 used technology that was less environmentally friendly. This was because regulations in most countries were relatively lax, hence vehicles produced during that period tended to generate more pollutants and greenhouse gases. After 2010, emission standards for vehicles began to tighten, and vehicles manufactured after were expected to produce lower emissions.

Multiple linear regression analysis was used to test the influence of vehicle characteristics (independent variables) including Cylinder Capacity (X_1), Travel Length (X_2), Vehicle Age (X_3), and Vehicle Maintenance (X_4) on exhaust emissions (Y). The result of the multiple linear regression test yielded the following model:

$$Y = 0{,}374 + 0{,}00001728X_1 - 0{,}00000003163X_2 + 0{,}005X_3 + 0{,}498X_4 + \varepsilon$$

Where:

Y = Opacity (%HSU)

X_1 = Cylinder Capacity (CC)

X_2 = Travel Length (KM)

X_3 = Vehicle Age (years)

X_4 = Maintenance

The positive coefficient value for the Cylinder Capacity (X_1) characteristic, which is 0.00001728, indicates that for every 1 cc rise in the cylinder capacity, the exhaust emission content (%HSU) increases by 0.00001728%. However, in this study, Cylinder Capacity (X_1) is not statistically significant in influencing the %HSU content. These findings differ from some previous studies, where cylinder capacity significantly affects the %HSU content. Cars with cylinder capacities ranging from 1600 cc to 2800 cc show significant differences compared to those with cylinder capacities of 2900-4200 cc. The higher the cylinder capacity of diesel-fueled cars, the lower the opacity produced except for vehicles at 4200 cc. This difference is suspected to be due to the majority of vehicles being produced after 2010 and having a GVW > 3.5 tons. Vehicles manufactured after 2010 have better environmentally friendly technology when compared to before 2010. Likewise, vehicles with GVW > 3.5 tons have environmentally friendly exhaust emission technology [4], and cylinder capacity does not affect emission test results. The porous part of the exhaust, located either in the neck or between the tool and the exhaust neck, is a suspected factor that is difficult to determine. This exhaust leak significantly affects the results of the emission collection process since not all of the smoke will be drawn into the tool, thus leading to inaccurate measurements [5].

The exhaust emission of a vehicle is directly related to the cylinder capacity. Increasing the engine size results in a corresponding increase in exhaust emissions. This phenomenon is caused by an imbalance in the air-fuel ratio during the combustion process. Any variation in these two crucial components leads to the formation of *Particulate Matter* (PM). Incomplete fuel combustion, resulting from an imbalanced fuel-air reaction also leads to the formation of PM, which is known to pose a significant threat to living organisms [6][7].

The coefficient value is negative for the characteristic of Travel Length (X_2) of 0.00000003163, meaning that for every 1 KM increase in vehicle travel length, the % HSU content decreases by 0.00000003163%. The findings contradict the hypothesis that postulates a correlation between % HSU and mileage. The distance traveled by the vehicle may have an impact on the accumulation of %HSU. This is because the accumulation of residue in the combustion chamber can cause scale which affects the emission load. The %HSU content produced is directly proportional to the travel distance of the motor vehicle [7][8].

The coefficient value for the Vehicle Age characteristic (X3) is positive, with a value of 0.005. Therefore, for every additional year of the vehicle's age, the %HSU content increases by 0.005%. The results show that there is a correlation between the age of the vehicle and the %HSU content of its exhaust emissions. As the age of the vehicle increases, the %HSU content tends to be higher. However, the results indicate that there is no significant relationship or influence between vehicle age and %HSU. Age correlates with the emission levels produced, where older vehicles tend to emit a greater volume of emissions [9][10]. In essence, the older the engine, the greater the amount of emissions released. This is because the machine is working hard and not functioning optimally [11][12] [13].

The coefficient value of 0.498 for the characteristics "maintenance" (X_4) indicates that a decrease in maintenance results in a 0.498% increase in the %HSU content. This highlights the importance of effective maintenance since poor maintenance can lead to an increase in %HSU [14][15]. The study also found that maintenance plays a crucial role in controlling emission levels, and well-maintained vehicles emit fewer emissions. Regular engine servicing can result in emission reduction, while infrequent servicing leads to higher emissions. Routine servicing intervals can minimize wear and tear, as well as improve airflow and fuel delivery to the engine, resulting in better combustion efficiency and lower emission concentrations.[7].

4. Conclusion

In conclusion, the assessment of exhaust gas emissions from goods transport trucks in Manokwari Regency reveals important findings. The average emission level of exhaust gas, measured as %HSU, is calculated to be 49.03%. This indicates that the majority of trucks operating in the region emit exhaust gas %HSU below the established threshold, accounting for 53.33% of the vehicles. However, it is concerning that 46.67% of the trucks did not pass the emission test as their %HSU emissions exceeded the set threshold, posing a potential risk of air pollution. This highlights the need for effective measures to mitigate and control emissions from these vehicles. The analysis also indicates that several vehicle characteristics, namely Cylinder Capacity (X1), Travel Length (X2), Vehicle Age (X3), and Vehicle Maintenance (X4), collectively contribute to the %HSU emission value (Y). These variables collectively influence the overall emission levels. Moreover, when examining the individual impact of each variable, it is observed that Vehicle Maintenance (X4) is the sole characteristic that influences the %HSU value.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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