

“ANALYSIS OF AIR POLLUTION CAUSED BY VEHICLES ON ARTERIAL ROADS IN BOGOR CITY”

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Abstract

With the growth in the number and types of vehicles in Bogor City, there are new conveniences and challenges. One of them is the large number of vehicle exhaust emissions that mix with each other in the air, causing air pollution caused by vehicles passing through arterial roads and causing congestion. This study aims to determine how much pollution caused by vehicles, especially those generated on arterial roads in Bogor City and is expected to help related parties to take mitigation actions. This research was conducted using the VKT (Vehicle Kilometer-Traveled) method to calculate vehicle pollution and the Simple Box Model to determine the amount of types of emissions produced. The vehicle exhaust emissions produced are quite high, therefore mitigation measures need to be taken.

Keywords : Box Model, Vehicle, Air Pollution, Vehicle Kilometer-Travelled, Arterial Road.

Introduction

Air pollution is one of the environmental problems that is increasingly worrying in various parts of the world, including Indonesia. Along with the increase in industrial activities, growth in the number of motor vehicles, and rapid urbanization, air quality is decreasing and has a direct impact on human health, ecosystems, and global climate change. According to the Asian Development Bank (2003), the transportation sector is the one that produces the most air pollution, with the production of hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NO_x), and particulates (PM) ranging from 87%. In research (Nor Asri, Eka Sari, and Meidiana Jurusan Perencanaan Wilayah dan Kota 2022), it is stated that motorized vehicles are the largest contributor to carbon monoxide (CO) emissions with a total of 76.4% of total emissions.

Bogor City is one of the cities in West Java Province which has an area of approximately 111.39 km². Bogor City is a city that is experiencing rapid economic growth, because of its location that can support the Capital of Indonesia, Jakarta. This causes a decrease in air quality so that it can cause disease for the community. Reporting from the IQAir website

with sources from the Ministry of Environment, currently the Bogor City air quality index is at 129 based on EPA (Environmental Protection Agency) standards set in 2024, which means it is quite unhealthy, especially for people with certain diseases. The poor air quality is caused by several sectors, including the transportation sector.

In research (Inigo Kila Adinatha dan Arif, 2022) which examines the greenhouse gas inventory in Bogor City, the transportation sector is the second largest contributor after the industrial sector, which is 532,836 tons of CO₂ eq. In addition, in a study (Rahma Rinjani et al., 2016) which examined the carbon sequestration potential of green lanes in Bogor City, it showed that on roads that become green lanes, which is Pajajaran Street, and KH. Sholeh Iskandar Street, the carbon produced is high enough that it still requires trees as carbon sequestration. The results of these two previous studies show that air pollution is a serious problem for the people of Bogor City, so research is needed to find out how air conditions in Bogor City and government efforts to deal with it.

Research Method

This research focuses on the problem of the amount of exhaust emissions produced by various types of vehicles traveling on Arterial roads in Bogor City, and also identifies things that can be done to reduce these emission levels and efforts to improve air quality in Bogor City.

To assess the amount of vehicle exhaust emissions on arterial roads in the city of Bogor, a survey method was used with a quantitative approach using the Vehicle Traveled Kilometre (VKT) and Box Model models. The survey was conducted on the number of vehicles traveling on arterial roads in Bogor City based on the type of vehicle, which was then multiplied by the length of the road and the exhaust emission factor that has been determined in the applicable regulations.

The calculated emission load is then projected using the Simple Box Model approach to find out how the concentration of these emissions in the air around the arterial roads in Bogor City. The projection results are then compared with the thresholds for each pollutant in accordance with applicable regulations, which can then be used as suggestions for improvement for the government and the Bogor City Environment Agency.

Discussion

The land transportation sector, particularly motor vehicles on roads, is a major contributor to air emissions in Indonesia's urban areas, including Bogor City. The growth in

the number of vehicles that is not proportional to the capacity of road infrastructure has led to a significant increase in the amount of exhaust emissions. Study conducted by (Apriyana, Ergantara, and Nasoetion, 2023) which examines CO emissions due to congestion in Bandar Lampung City shows the number of vehicles during congestion has a positive and strong correlation ($R = 0.883$) which means that if the number of vehicles increases, the amount of CO emissions will also increase. Emissions from motor vehicles produce various harmful pollutants such as carbon monoxide (CO), nitrogen dioxide (NO₂), hydrocarbons (HC), sulfur dioxide (SO₂), and fine particles (PM_{2.5} and PM₁₀), which contribute greatly to ambient air pollution.

Bogor City as a satellite city of Jakarta also experiences additional pressure from the high daily mobility of people who work or move across the city, especially through highways. According to data from the Regional Revenue Agency of West Java Province, the number of vehicles in Greater Bogor, which includes Bogor City, recorded 169,050 units of passenger cars, 1,003 units of buses, 45,186 units of trucks, and 1,410,656 units of motorcycles. These vehicles contribute various types of pollutant emissions, including carbon monoxide (CO), nitrogen dioxide (NO₂), sulfur dioxide (SO₂), hydrocarbons (HC), and fine particles such as PM₁₀ and PM_{2.5}. These substances are the result of burning fossil fuels (gasoline and diesel) in the vehicle engine.. Based on study by (Arifin et al., 2019) that examined PM_{2.5} concentrations using the AERMOD model, it shows that in the Bogor City protocol route, the highest PM_{2.5} concentrations are at traffic congestion points such as Pajajaran Street and KH Sholeh Iskandar Street which can exceed 80 µg/Nm³ during peak hours, exceeding the threshold recommended by WHO. In addition, research by (Adli dan Febrita, 2024) used the AERMOD model to map the distribution of PM₁₀ from road traffic in Gunung Putri, Bogor Regency. The results showed high concentrations of particulates in areas with high heavy vehicle volumes and limited vegetation. Although the study was conducted in the regency, the context of urbanization and traffic integration into Bogor City makes the findings relevant for understanding the regional impacts of transport.

To deal with these emission problems, efforts need to be made by the government. A research by (Rahma Rinjani et al., 2016) mentioned that it is necessary to increase the number and types of plants that are able to absorb high carbon such as Lagerstroemia, Samanea Saman, Pterocarpus Indica, Switenia Mahagoni, Ficus benyamina, Ceiba petandra, but this method is only as a step to reduce the amount of emissions that are already spread in the air, and not as a preventive measure. Therefore, as a preventive measure in research (Inigo Kila Adinatha dan Arif, 2022) according to Lestari in the research “*Adaptation and mitigation strategies for*

reducing greenhouse gas (GHG) emissions in the transportation sector and the waste sector in Batu City” in 2017, there are 3 (three) mitigation strategies that can be done to overcome these emission problems, namely avoid / reduce or avoid or reduce travel or the need for travel (especially in urban areas) through land stewardship, shift or switch to more environmentally friendly modes of transportation, and improve or improve the energy efficiency of transportation modes and vehicle technology.

According to the Green Transportation study (Dwiputri et al., 2021) which examines the compatibility of environmentally friendly transportation in Bogor City, there are several compatibilities of Bogor City in meeting 9 (nine) Green Transportation indicators by comparing with the application of Green Transportation in several countries. Based on the results of the analysis of best practice green transport in Australia, the decline in the growth rate of motorized vehicles tends to increase and it is considered very difficult to reduce the increase in motorized vehicles at this time, because it has not been supported by adequate public transportation. Furthermore, the level of fuel use in the city of Bogor, the level of fuel consumption in the city of Bogor is still increasing every day, and this is one of the things that causes air pollution, in contrast to one of the cities, Curitiba, which annually uses a fuel saving system that is used as transportation fuel by means of community cooperation with the government in the use of mass public transportation facilities. The third indicator of Green Transport is the use of Green Fuel, in the use of fuel for motorized vehicles, both in the city of Bogor and in several European cities both have established the concept of green, where the use of Trans Pakuan fuel in the city of Bogor is using processed cooking oil in addition, it has been stipulated in the RTRW policy regulation, that the use of fuel is to use LPG gas fuel just like what is done in Europe by using BBG. The fourth indicator is travel time and distance, by knowing the frequency of public transportation trips in Bogor City, it can be seen that the number of city transportation in Bogor City is high enough so that city transportation in Bogor City can serve all people in Bogor City. Similar to cities in Australia, the decline in private vehicle ownership concludes that to reduce private vehicles requires a decent and comfortable SAUM so that in addition to the frequency of vehicles, the facilities and infrastructure owned by mass transit must be in accordance with the needs of the people. The fifth indicator of Green Transport is the level of use of public transportation, the level of use of mass public transportation that refers to the green concept should be more than 70% of the population, but by looking at the condition of the use of public transportation in the city of Bogor, it can be seen that there are still low users of public transportation in the city of Bogor, which is only 23% of the population, this is due to the lack of facilities and infrastructure provided by the

government in mass public transportation services, causing a lack of public interest in the use of public transportation. Mass Transportation is the sixth indicator of the Green Transport concept, Mass transportation ownership in the city of Bogor is complete starting from City Transportation, Inner City Provincial Transportation (AKDP), Trans Pakuan, City bus transportation, and Trains. Of all the existing public transportation, it is concluded that the number of transportation can almost serve almost all people in the city of Bogor, but the highest rate of use of city transportation is still considered less efficient for green transport because city transportation has a small passenger capacity and still makes a high contribution to greenhouse gases. This public transportation problem is also influenced by the factor of user satisfaction with public transportation, if the customer is satisfied with the value provided by the product or service, it is very likely to become a customer for a long time (Kumala Dewi et al. 2022). Unlike in the City of Curitiba, BRT (Bus Rapid Transit) mass public transportation can carry more than 2 million passengers every day with a bus capacity of 110-270 people/bus. The seventh indicator of Green Transport is bicycle lanes, where bicycle lanes are not yet available in Bogor City, but in the Bogor City Regional Regulation Number 8 of 2011 concerning the Bogor City Regional Spatial Plan, there is a plan to provide special lanes for non-motorized vehicles. Bogor City can follow the example of Amsterdam City by developing facilities for bicycles, such as bicycle lanes, bicycle parking facilities, and others. Bogor City has obstacles in developing bicycle lanes, namely hilly topography, but there are several segments in Bogor City that have gentle topography conditions so that bicycle lanes can be developed. The eighth indicator of green transportation is pedestrian facilities, Bogor City already has several points of pedestrian facilities that connect the movement of people moving from mass transportation such as at the Railway Station. Bogor City also has a pedestrian facility development plan that has the legality of Bogor City Regional Regulation Number 8 of 2011 concerning the Bogor City Spatial Plan 2011-2031. But so far the distribution of pedestrian facilities in Bogor City is still not comprehensive and has not been integrated with mass public transport infrastructure (Trans pakuan) The last green transport indicator is the Smart Transportation Management System, several Smart Transportation Management System efforts in Bogor City have been carried out, one of which is motor vehicle emission gas testing conducted by the Transportation Agency. This testing program is still an initial effort from STMS which has not been able to reduce vehicle exhaust gases, efforts made by Singapore have not been accommodated in Bogor City such as vehicle restrictions using Electronic Road Pricing. The ERP concept should be very suitable to be applied in Bogor City which is reflected

in the concentration of Bogor City transportation activities in the City Center Area (Central Bogor).

The Vehicle Kilometre-Travelled (VKT) method is used to calculate the amount of exhaust emission loading generated by vehicles calculated based on the length of the vehicle trip, the type of vehicle, and the type of emissions produced by the vehicle based on the vehicle emission factor issued by the Ministry of Environment. (Nor Asri et al. 2022). Then, the emission load from the VKT model calculation is converted into a form of emission concentration in the air using a simple Box Model approach. The box model is used to estimate the average concentration of pollutants in an area that is assumed to be a box where emission sources are evenly distributed on the bottom surface of the box, in which an activity that produces gas emissions occurs (Setiyo Huboyo and Samadikun 2018). This model takes into account meteorological factors such as wind direction and speed, and mixing height.

Conclusion

The results of this study show that the land transportation sector, especially motor vehicles, is a major contributor to air pollution in Bogor City. The increasing number of vehicles is not matched by the development of adequate road infrastructure and public transportation systems, resulting in significant traffic congestion and a drastic increase in exhaust emissions.

Air pollutants generated from motor vehicle activities, such as carbon monoxide (CO), nitrogen dioxide (NO₂), sulfur dioxide (SO₂), hydrocarbons (HC), and fine particulate matter (PM_{2.5} and PM₁₀), have been identified as dominant factors in reducing ambient air quality in urban areas. The concentrations of these pollutants are particularly high in locations with high levels of traffic congestion, such as at Pajajaran Street and KH Sholeh Iskandar Street.

Bogor City also experiences additional mobility pressures due to its position as a satellite city of Jakarta, where daily commuting activities contribute significantly to traffic and emission loads. Data from government agencies show that the number of motor vehicles in Greater Bogor has exceeded 1.6 million units, with motorcycles dominating as the main mode of public transportation. Various measures have been taken by the local government, such as the provision of public transportation such as Trans Pakuan and BusKita. However, the effectiveness of these programs is still not optimal. This is due to the low attractiveness of

public transportation, limited supporting infrastructure, and lack of integration between modes of transportation.

Based on the VKT calculation, it is found that the total emission load from all arterial roads in Bogor City exceeds the emission threshold set by the government and mostly comes from private vehicles, especially motorcycles, then private cars, and the rest from public transportation, buses, trucks, and diesel-fueled cars. And especially on Jalan Raya Tajur which connects Bogor City and Bogor Regency. The results of the Box Model calculation show that the amount of emissions concentrated in the ambient air around arterial roads in Bogor City still exceeds the specified threshold, especially for TSP emissions.

From the results it can be concluded that controlling transportation sector emissions in Bogor City requires a more comprehensive approach, including limiting private vehicles, developing affordable and efficient public transportation systems, increasing the use of clean energy, and urban spatial planning that supports sustainable mobility. In addition, lessons learned from other cities that have successfully implemented environmentally friendly transportation systems can be used as a reference for the development of transportation policies in Bogor City.

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