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VEHICLE VOLUME AND CARBON MONOXIDE AND NITROGEN OXIDE EMISSIONS ON WEEKDAYS AND WEEKENDS ON ANGGAJAYA STREET, SLEMAN

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ABSTRACT

Vehicle Volume And Carbon Monoxide And Nitrogen Oxide Emissions On Weekdays And Weekends On Anggajaya Street, Sleman. *Anggajaya Road, located in Condongcatur Village, Depok Subdistrict, Sleman Regency, is directly connected to the Ring Road Utara Road and serves as a residential area with boarding houses, shops, and terminal.This study aims to determine the traffic volume and exhaust emissions of carbon monoxide and nitrogen oxide gases on Anggajaya Road, Sleman Regency. The research method employed was observational, conducted during weekends and weekdays from 09.00-11.00 WIB. The observed types of vehicles include motorcycles, cars, trucks, and buses. The result was that the vehicle volume was 0,335 smp per second on weekend and 0,277 smp per second on weekday. The emission levels of carbon monoxide and nitrogen oxide were higher during the weekend compared to weekday.*

INTRODUCTION

Traffic density in Indonesia is expected to continue increasing in line with the country's population growth. Traffic volume on a road segment is a variable in the calculation process that relates to the number of movements per unit of time at a specific location[1]. Vehicles occupying or passing through road lanes in Indonesia are predominantly motor vehicles powered by petroleum-based fuels. Petroleum fuels are derived from fossil fuels and are classified as non-renewable energy sources[2]. In Indonesia, motor vehicles typically use gasoline and diesel as fuel. According to data from the Ministry of Energy and Mineral Resources (ESDM) in 2022, gasoline-powered vehicles accounted for 48%, while diesel and biodiesel-powered vehicles made up 46%. Gasoline is one of the petroleum fractions composed of hydrocarbon chains such as isooctane and several straight-chain hydrocarbons like heptane[3]. Meanwhile, diesel fuel is used in diesel engine vehicles, which utilize compression heat to ignite the fuel in internal combustion engines[4].

Each motor vehicle produces major exhaust gases, including carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), sulfur oxides (SOx), and particulates (PM10)[5]. These vehicle emissions contribute to air pollution, which refers to the presence of foreign substances in the atmosphere in amounts sufficient to alter its normal composition[6]. Air pollution can lead to health problems and mortality. According to the World Health Organization (WHO) in 2019, air pollution-related deaths were attributed to heart disease (25%), stroke (24%), chronic obstructive pulmonary disease (43%), and lung cancer (29%) [7]. Motor vehicle emissions fall under the transportation sector, which is one of the sectors measured in the air quality index. The air quality index, derived from the annual average

concentrations of air pollutants such as NO_2, SO_2, and $PM_{2.5}$ in Sleman Regency, was recorded at 77.46 in 2019. This level increased to 89.51 in 2023[8]. According to data from the Regional Development Planning Agency (BAPPEDA) of the Special Region of Yogyakarta Province, emission measurements conducted in 2019 at Seturan, located on the North Ring Road, recorded CO levels at 659.01 $\mu g/m^3$, NO_2 at 141.51 $\mu g/m^3$, and SO_2 at 15.19 $\mu g/m^3$[9].
One of the roads directly connected to Yogyakarta's North Ring Road is Anggajaya Street, located in Condongcatur Village, Depok District, Sleman Regency. The area surrounding Anggajaya Street consists of residential zones, boarding houses, commercial establishments, and the Condongcatur Terminal. Most vehicle movement occurs from north to south, exiting toward Affandi Street and the Ring Road, while significant incoming traffic flows from the south via Affandi Street and the Ring Road. High traffic activity in this urban area, coupled with limited vegetation, contributes to elevated levels of vehicle exhaust emissions in the air. This study aims to determine the traffic volume and vehicular exhaust emissions of CO and NOx on Anggajaya Street, Condongcatur, Depok District, Sleman Regency.

MATERIALS AND RESEARCH METHODS

This study is an observational research conducted in March 2024, with treatments based on different observation days, namely Weekend (Saturday, March 9, 2024) and Weekday (Wednesday, March 13, 2024), at the same location and time—on Anggajaya Street, Condong Catur, Depok, Sleman, Yogyakarta—from 09:00 to 11:00 Western Indonesian Time (WIB) for both observation days. The study was carried out by counting vehicles, which were categorized based on vehicle type and fuel used. Measurements of road length and width were also conducted to calculate vehicle fuel consumption.
Vehicle categories were classified into motorcycles, light four-wheeled gasoline-powered vehicles, light four-wheeled diesel-powered vehicles, and heavy four-wheeled diesel-powered vehicles. Observations and vehicle counts were conducted every 15 minutes over a 2-hour period. The data obtained were then processed and calculated using fuel consumption formulas and emission factors based on the Indonesian Highway Capacity Manual (Pedoman Kapasitas Jalan Indonesia)[10].

Formula: Vehicles/PCU

$$\sum \text{Vehicles (per PCU)} = \text{Vehicle type} \times \text{PCU index}$$

PCU Coefficients:
Motorcycles (MC) : 0.2 PCU
Light Vehicles (LV) : 1.0 PCU
Heavy Vehicles (HV) : 1.3 PCU

Fuel Consumption Formula

$$\text{LOS} = \frac{\text{Traffic Volume}}{Road\ Capacity}\ \text{PCU/Hours/m}$$

Emission Factor Formula

$$Q = n \text{ x } (FE \text{ X } k)$$

Q : Emitted gas emissions
n : Traffic Volume (PCU/second)
k : Fuel Consumption (liters)
FE : Emission Factor of CO or NO Gas (grams/Liter)

RESEARCH RESULTS AND DISCUSSION

Table 1. Number of Vehicles on Weekend and Weekday

Observation Time	Motorcycle	Car	Truck	Bus	Total
Weekend	1645	523	21	0	2189
	1097	451	27	1	1576
Total	2742	974	48	1	**3765**
Weekday	1463	292	31	1	1787
	1253	353	26	0	1632
Total	2716	645	57	1	**3419**

The observation of vehicle count and traffic volume during the weekend and weekday was conducted over a 90-minute period. The number of vehicles observed on Anggajaya Street was higher during the weekend compared to the weekday (Table 1). However, the number of diesel-engine vehicles was found to be greater on the weekday.

Table 2. Total Vehicle Volume

Observation Time	Volume of Each Vehicle Type (PCU/second)				Total Vehicle Volume (PCU/second)
	Motorcycle	Car	Truck	Bus	
Weekend	0,127	0,180	0,027	0,001	0,335
Weekday	0,126	0,119	0,032	0,001	0,277

The total vehicle volume is proportional to the vehicle count expressed in passenger car units (PCU). The total vehicle volume was higher during the weekend, amounting to 0.335 PCU/second (Table 2). The calculation of total vehicle volume uses passenger car units (PCU), which represent the relative interaction between vehicles and traffic flow in relation to a standard passenger car under specific road and traffic conditions[11].
The higher vehicle count and volume observed on weekends is attributed to increased travel activities during this period, whereas the weekday observation from 09:00 to 11:00 a.m. corresponds to working and school hours, resulting in fewer gasoline-powered vehicles passing through. Diesel-powered vehicles commonly observed include box trucks, trucks, and buses, which relate to the occupational profile of their owners as goods delivery drivers.

Table 3. Carbon Monoxide (CO) Emission Intensity on Anggajaya Street

Observation Time	CO Emission Rate (g/second)				Total Emission Rate (g/second)
	Motorcycle	Car	Truck	Bus	
Weekend	0,112	0,455	0,013	0,000	0,580
Weekday	0,111	0,301	0,016	0,000	0,428

The total carbon monoxide (CO) emission rate on Anggajaya Street was highest during the weekend. The elevated CO emission rate on weekends is attributed to the greater number of vehicles passing through Anggajaya Street. According to Afuye & Ojeh, CO concentrations show a significant difference between holidays and weekdays. The higher CO concentrations during holidays are due to increased public mobility as people tend to engage in weekend activities and events, resulting in more motor vehicle use[12]. Flaschbart & Ott (2019) reported that the average CO emission concentration on roadways increases linearly each year due to variability in average trip numbers and traffic conditions annually[13]. Rosa (2015) stated that traffic conditions, such as high motor vehicle density, lead to higher CO concentrations in the air compared to roads with lower traffic density[14][17].

Carbon monoxide is a gas released into the atmosphere through incomplete combustion of carbon-based materials, in this case, originating from motor vehicle engines[15]. This gas is characterized by being odorless, colorless, tasteless, and lighter than air[16].The dispersion of

CO emitted from vehicle exhaust is influenced by the random motion of air on roadways. Turbulence and mechanical mixing of pollutants released through vehicle exhaust into ambient air cause the dispersion mechanism of carbon monoxide gas [13] [17].
Exposure to carbon monoxide can cause eye irritation, shortness of breath, dizziness, concentration problems, fatigue, visual disturbances, nausea, and vomiting. These symptoms occur when carboxyhemoglobin (COHb) concentration in the blood reaches 2.1%–2.9%[18]. CO enters the human body through the respiratory system and diffuses across the alveolar membrane together with oxygen. The dissolved gas forms COHb after binding with hemoglobin[7].

Table 4. Nitrogen Oxide (NOx) Emission Rate on Anggajaya Street

Observation Time	NO_x Emission Rate (g/second)				Total Emission Rate (g/second)
	Motorcycle	Car	Truck	Bus	
Weekend	0,002	0,023	0,028	0,000	0,054
Weekday	0,002	0,015	0,034	0,000	0,051

The emission rates of carbon monoxide and nitrogen oxides were higher on weekends than on weekdays. The total CO emission rate on weekends was 0.580 grams per second, compared to 0.428 grams per second on weekdays. NOx emission rates were 0.054 grams per second on weekends and 0.051 grams per second on weekdays.
Recommendations include measuring abiotic climatic factors during observations for further analysis in this study. Moreover, identifying vehicle subtypes based on fuel types is suggested for future research The emission rate of nitrogen oxides (NOx) showed the highest total emission rate during the weekend, at 0.054 grams per second. However, the total emission rate difference was not statistically significant. The emission rate from trucks was actually higher on weekdays compared to weekends, whereas motorcycles and cars emitted more on weekends. The higher NOx emission rate from trucks is due to the use of diesel engines. Diesel engines emit more nitrogen oxides than carbon monoxide[19]. According to Pielecha et al. (2019), NOx emissions from real-world driving conditions are approximately three times higher than those from gasoline engines[20]. Agudelo-Castaneda et al. (2014) reported that NOx emissions from heavy-duty vehicles are five times greater than those from light-duty gasoline-powered vehicles[21]. Biodiesel slightly increases NOx emissions[22].
Nitrogen dioxide originates from combustion, natural sources, and emissions related to ozone in the troposphere, and is associated with acid rain on Earth. Traffic emissions, which are a primary source of NOx gases, depend on the vehicle type, size, and fuel used. Nitrogen dioxide, a reddish-gray gas formed by reaction with oxygen, can cause eye and lung irritation in humans[23][24].Recent studies indicate that NOx affects human health, particularly in individuals with magnesium deficiency, leading to cardiovascular diseases, pulmonary and respiratory dysfunction, and neurological disorders[25] [26].
Nitrogen oxides (NOx) exist in several bonded forms, including nitric oxide (NO) and nitrogen dioxide (NO_2), both of which pose health risks. High inhalation exposure to nitrogen oxides irritates the upper respiratory tract and lungs. NOx is heavier than oxygen, so exposure in enclosed spaces may cause breathing difficulties. Wen et al. (2017) found that ambient air pollutants are influenced by traffic flow rates, vehicle speed, and estimated pollutant dilution due to vehicle-induced turbulence[27]. Additionally, meteorological factors affect the dispersion of pollutant concentrations in ambient air. Annual air quality monitoring is conducted to estimate pollutant distribution within specific areas or road segments[17].

CONCLUSIONS AND RECOMMENDATIONS

Based on observations and measurements of vehicle volume and the emission rates of carbon monoxide and nitrogen oxides on Anggajaya Street, Sleman Regency, the following conclusions were drawn: The total vehicle volume was higher on weekends, with 0.335

PCU/second compared to 0.277 PCU/second on weekdays. Thus, total vehicle volume during weekends exceeded that of weekdays. The emission rates of carbon monoxide and nitrogen oxides were higher on weekends than on weekdays. The total CO emission rate on weekends was 0.580 grams per second, compared to 0.428 grams per second on weekdays. NOx emission rates were 0.054 grams per second on weekends and 0.051 grams per second on weekdays.
Recommendations include measuring abiotic climatic factors during observations for further analysis in this study. Moreover, identifying vehicle subtypes based on fuel types is suggested for future research.

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