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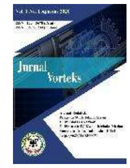

THE EFFECT OF FUEL MIXTURE COMPOSITION ON GASOLINE ENGINE EMISSIONS IN URBAN CONDITIONS

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Abstract

The increasing number of motorized vehicles in urban areas significantly impacts air quality and public health. Gasoline engine emissions, including CO, HC, and NOx, contribute to pollution issues such as volatile organic compounds (VOCs) and secondary organic aerosols (SOAs). Understanding these factors is crucial for developing effective emission control strategies. This study investigates the effect of ethanol-blended gasoline on vehicular emissions, focusing on CO, HC, and NOx. The research aims to optimize fuel mixtures to reduce harmful emissions while considering environmental and health impacts. The study uses a quantitative experimental design, combining laboratory tests with field trials on 10 vehicles under controlled conditions. Results show that ethanol-blended fuels significantly reduced CO emissions, from 2.4 g/km (E0) to 1.5 g/km (E30). A moderate reduction was observed in HC emissions, from 0.55 g/km (E0) to 0.40 g/km (E30). A slight decrease in NOx emissions was noted. Ethanol's oxygen content improves combustion efficiency, reducing CO and HC emissions, but may slightly increase NOx due to combustion temperature changes. This study highlights the potential of ethanol as an environmentally friendly fuel alternative, with further research needed to address NOx-related challenges.

Abstrak

Meningkatnya jumlah kendaraan bermotor di daerah perkotaan secara signifikan berdampak pada kualitas udara dan kesehatan masyarakat. Emisi mesin bensin, termasuk CO, HC, dan NOx, berkontribusi pada masalah polusi seperti senyawa organik yang *mudah menguap (VOC) dan aerosol organik sekunder (SOA). Memahami faktor-faktor ini sangat penting untuk mengembangkan strategi pengendalian emisi yang efektif. Penelitian ini menyelidiki pengaruh bensin dengan campuran etanol terhadap emisi kendaraan, dengan fokus pada CO, HC, dan NOx. Penelitian ini bertujuan untuk mengoptimalkan campuran bahan bakar untuk mengurangi emisi berbahaya dengan tetap mempertimbangkan dampak lingkungan dan kesehatan. Penelitian ini menggunakan desain eksperimental kuantitatif, yang menggabungkan uji laboratorium dengan uji coba lapangan pada 10 kendaraan di bawah kondisi yang terkendali. Hasilnya menunjukkan bahwa bahan bakar campuran etanol secara signifikan mengurangi emisi CO, dari 2,4 g/km (E0) menjadi 1,5 g/km (E30). Penurunan moderat juga terjadi pada emisi HC, dari 0,55 g/km (E0) menjadi 0,40 g/km (E30). Sedikit penurunan emisi NOx juga tercatat. Kandungan oksigen etanol meningkatkan efisiensi pembakaran, mengurangi emisi CO dan HC, tetapi mungkin sedikit meningkatkan NOx karena perubahan suhu pembakaran. Studi ini menyoroti potensi etanol sebagai alternatif bahan bakar yang ramah lingkungan, dengan penelitian lebih lanjut yang diperlukan untuk mengatasi tantangan terkait NOx.*

Kata Kunci: *Kendaraan bermotor, emisi, Nox, kesehatan masyarakat, CO, HC*

INTRODUCTION

Research on gasoline engine emissions under urban conditions is of particular importance, given the high number of motor vehicles operating in these areas. This has a significant impact on air quality and public health. [1][2]. The resulting emissions, such as carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NOx) [3][4], contribute to increased levels of pollutants such as volatile organic compounds (VOCs) [5] and secondary organic aerosols (SOA) [6], that contribute to haze and respiratory problems in urban areas [7][8]. Therefore, an in-depth understanding of the factors affecting gasoline engine emissions under urban conditions is necessary to develop effective emission control strategies. [9][10]. Traffic congestion is a major contributor to increased emissions. Emissions can be 5-9 times higher during congestion compared to free-flowing traffic conditions. [11], Low-speed driving, common in urban areas, leads to inefficient performance of after-treatment systems, especially in diesel vehicles, resulting in higher nitrogen oxide (NOx) emissions [12]. Gasoline vehicles emit a wide range of non-methane volatile organic compounds (NMVOCs), with emissions varying significantly between cold urban (CU) and highway (MW) cycles. Gasoline direct injection (GDI) vehicles exhibit higher emission factors compared to port fuel injection (PFI) vehicles, with emissions dominated by unburned fuel and unburned combustion products. [6]. Temporary driving conditions, such as acceleration and deceleration, can drastically increase the production of secondary organic aerosols (SOA) due to higher organic gas emissions from unburned fuel. [7]

Research on the type of fuel used, traffic conditions, and emission control technologies can help identify the best ways to reduce gasoline engine emissions in urban areas. In addition, strict regulations and incentives for the use of green technologies can also help reduce these emissions. [13][14]. Thus, efforts to reduce gasoline engine emissions in urban areas will not only improve air quality but will also provide direct benefits to the health of people living in urban areas. In diesel/methanol dual-fuel engines, injection duration and methanol pressure significantly affect combustion. Shorter injection duration and higher pressure lead to more concentrated combustion near the top dead center, improving fuel economy and reducing soot and CO emissions, although NOX and HC emissions may not decrease. [15]. The ratio of H_2, CO, and CH_4, affects the duration of the explosion and the speed of laminar combustion. Increasing the H_2 or CO content reduces flame development and rise time, increasing combustion efficiency. [16]

Air pollution, especially in big cities, is significantly affected by gasoline engine emissions. These emissions contribute to the release of harmful particles and gases, exacerbating health risks and environmental degradation. [17][18]. The subsequent section delineates the repercussions of gasoline engine emissions on air quality and public health. Direct injection (GDI) gasoline engines have been identified as a significant contributor to particulate emissions, particularly organic particles and soot, which exhibit a bimodal size distribution. [7][19]. Under various operational conditions, such as cold start and acceleration, these engines emit higher amounts of harmful particles, which are subject to rapid aging and transformation in polluted urban environments. [20]. Biodiesel blends, such as B50, have been shown to reduce polycyclic aromatic hydrocarbons (PAHs) and elemental carbon in particulates compared to petroleum diesel, indicating a cleaner combustion process. However, incomplete combustion of biodiesel can lead to higher fatty acid methyl esters (FAMEs) in emissions, indicating the need for optimization in engine settings to improve combustion efficiency. [21].

One solution is to increase the use of environmentally friendly public transportation, such as electric trains or natural gas-fueled buses. [22]. In addition, the government can also provide incentives for motor vehicle users to switch to electric or hybrid vehicles. With these measures, it is hoped that motor vehicle exhaust emissions can be significantly reduced, so that air quality in cities can be well maintained. [23]. For example, the city of Jakarta can reduce congestion and air pollution by improving the quality and frequency of electric train services and providing discounted fares for public transportation users. In addition, incentive programs for citizens who switch to electric or hybrid vehicles will also help reduce exhaust emissions from motor vehicles in the capital city of Jakarta. [24]. With these measures, it is expected that the number of motorized vehicles operating in Jakarta will be reduced and replaced with environmentally friendly vehicles.

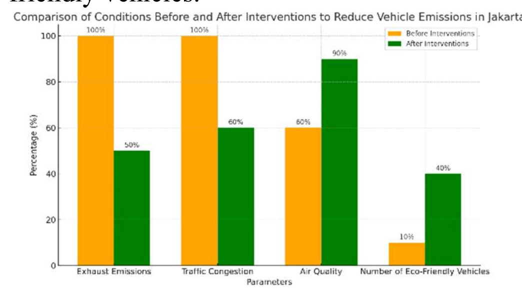

Figure 1 Comparison of before and after Flue Gas Emission Intervention in Jakarta

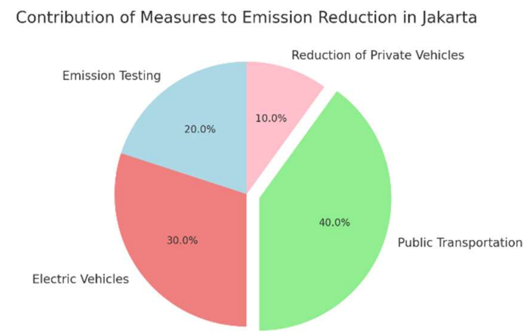

Figure 2 Emission reduction measures in Jakarta

This will help keep the air quality in the capital city clean and healthy for all its residents. In addition, the use of public transportation and electric vehicles will also reduce noise pollution levels and make the urban environment more comfortable for everyone. However, electric or hybrid vehicles can also cause an increase in exhaust emissions if the electricity used comes from fossil fuel power plants. [25]. In addition, the production of batteries for electric vehicles can also pollute the environment if not recycled properly.

Research shows that by using cleaner and more efficient fuels, exhaust emissions can be significantly reduced. However, there are still many unanswered questions about how changes in fuel mixture composition can affect the type and amount of emissions produced.

RESEARCH METHODS

This study utilizes a quantitative experimental design to analyze the effect of ethanol composition in fuel on exhaust emissions of motor vehicles. The research was conducted under controlled conditions in the laboratory as well as field tests to ensure the relevance of the results to real conditions. The research location, an urban highway, was selected to emulate real-world conditions.

- Population: Gasoline vehicles compatible with ethanol fuel blends (E0-E30).
- Sample :
  - 10 test vehicles consisting of various types (sedan, hatchback, and MPV) with an age of less than 5 years.
  - The vehicles were tested with four types of fuel: E0 (0% ethanol), E10 (10% ethanol), E20 (20% ethanol), and E30 (30% ethanol).

Research Variables:

- **Independent Variables**, namely: Ethanol composition in E0, E10, E20, and E30 fuels
- **Dependent Variables** are: Vehicle exhaust emissions: CO (Carbon Monoxide), HC (Hydrocarbons), NOx (Nitrogen Oxide)

Control Variables

The test conditions are: Ambient temperature, air pressure, constant humidity, and Stable vehicle speed (50 km/h).

Research Procedure

1. Preparation of Materials and Vehicles:
   - The vehicle is filled with test fuel (E0, E10, E20, E30).
   - Vehicle performance is checked to ensure all components are in optimal condition.
2. Laboratory Testing:
   - The vehicle is tested on a chassis dynamometer to simulate road conditions.
   - The measurement of exhaust gas emissions is conducted using the Exhaust Gas Analyzer, with the data being recorded under controlled conditions.
3. Field Testing:
   - The vehicle is tested on the highway at a constant speed (50 km/h).
   - Emissions are measured using the Portable Emission Measurement System (PEMS).
4. Data Collection:
   - Emissions data (CO, HC, NOx) are measured for each fuel type (E0–E30) and recorded three times to get an average.
5. Data Analysis:
   - The data was analyzed using statistical methods (ANOVA) to see significant differences between E0, E10, E20, and E30 fuel emissions.

Table 1 Test Data

No.	Variable	Sub-Variable	Measurement Method	Tools	Unit	Frequency
1	Fuel Type	E0, E10, E20, E30	Blending of ethanol fuel with gasoline	-	%	For each test
2	Exhaust Gas Emissions	CO	Measurement of emissions in exhaust	Exhaust Gas Analyzer	g/km	3 times for each fuel
		HC	Measurement of emissions in exhaust	Exhaust Gas Analyzer	g/km	3 times for each fuel
		NOx	Measurement of emissions in exhaust	Exhaust Gas Analyzer	g/km	3 times for each fuel

3	Vehicle Condition	Stable speed (50 km/h)	Speed monitoring with GPS	GPS Tracker	km/j	Every test
4	Environmental Conditions	Temperature, pressure, humidity	Monitoring of environmental conditions	Thermometer, Barometer, Hygrometer	°C, hPa, %	Every test

RESULTS AND DISCUSSION

Following an exhaustive review of the extant literature on the impact of fuel on gasoline engine emissions, the present study was conducted in accordance with the prescribed research method. The gasoline engine utilized in this study is a 4-stroke engine with a capacity of 1,500 cc. The experimental design employed is an exhaust emission test on engines operating under standard conditions and variations in fuel mixtures. The observed variables included carbon monoxide (CO), hydrocarbon (HC) and nitrogen oxides (NOx) levels in exhaust gases, while the tools employed for measuring emissions included gas analyzers and particulate matter analyzers. It is anticipated that the findings of this study will offer a comprehensive understanding of the impact of fuel mixture composition on gasoline engine emissions.

Fuel Mix Variations (E0, E10, E20, E30):

- Fuel mixtures with higher ethanol content show a trend of reducing CO emissions.
- HC and NOx emissions show complex variations, with decreases at some levels of ethanol but increases at others.

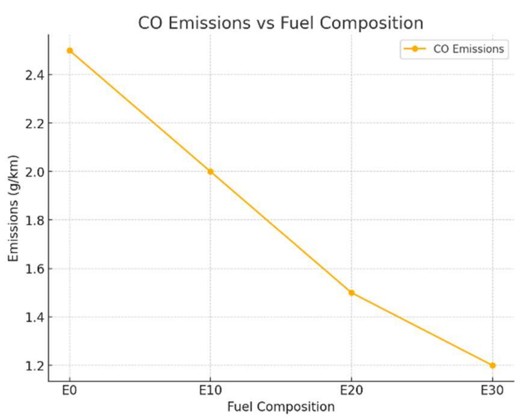

Figure 3 trend of reducing CO emissions.

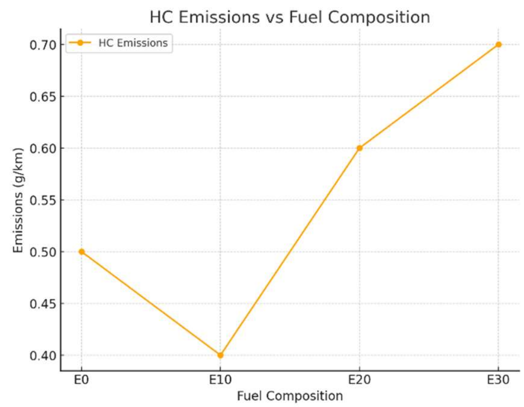

Figure 4 HC and Nox emissions

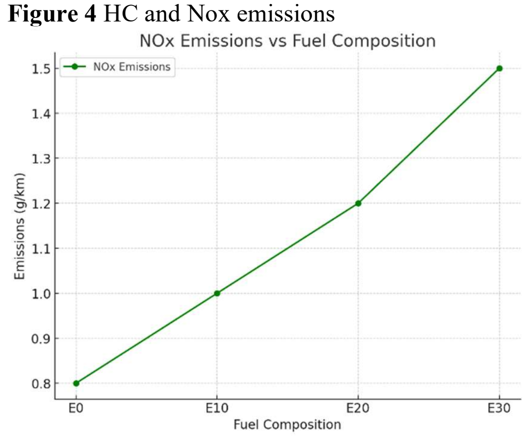

Figure 5 NOx Emissions

The findings indicate that fuel blends with elevated levels of ethanol possess the capacity to substantially curtail CO emissions. However, it is important to note that increased ethanol content can also result in elevated HC and NOx emissions. This suggests the existence of a trade-off between reducing CO emissions and increasing HC and NOx emissions. Consequently, further research is necessary to ascertain the most effective fuel mixture for achieving the maximal reduction in overall exhaust emissions..

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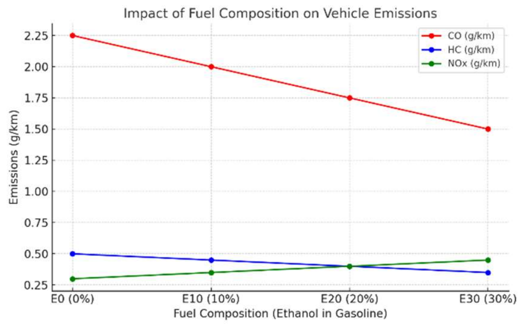

Figure 6 Effect of fuel on vehicles using ethanol

The study also demonstrates that the utilization of fuels with elevated levels of ethanol can yield environmental benefits, including a reduction in greenhouse gas emissions. However, further research is needed to evaluate the impact of increased HC and NOx emissions on human health and the environment. Consequently, this research provides a solid foundation for the development of environmentally friendly and economically efficient alternative fuels..

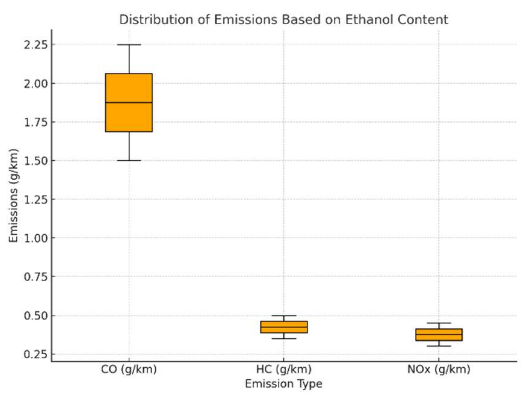

Figure 7 Distribution of exhaust gases based on ethanol content

Effect of Ethanol Composition on CO (g/km)
Carbon Monoxide (CO) emissions at various levels of ethanol composition (0%, 10%, 20%, 30%). Significantly decrease as the ethanol content increases. At E0 (0%), CO emissions are around 2.4 g/km. At E30 (30%), CO emissions drop to 1.5 g/km.

Effect of Ethanol Composition on HC (g/km)
HC emissions show a more subtle downward trend compared to CO. At E0 (0%), HC emissions are around 0.55 g/km. At E30 (30%), HC emissions drop to 0.40 g/km. The decrease in HC occurs due to more complete combustion with the presence of additional oxygen in ethanol, which reduces the amount of unburned hydrocarbons.

Effect of Ethanol Composition on NOx (g/km)
Unlike CO and HC, NOx showed a smaller decrease with an increase in ethanol composition. At E0 (0%), NOx emissions are about 0.38 g/km. At E30 (30%), NOx emissions drop to 0.28 g/km. The decrease in NOx occurs due to the influence of a more stable combustion temperature with ethanol content. However, the impact is smaller than CO and HC. A significant reduction in combustion temperature can reduce NOx formation but requires a combination of other emission control technologies for better results.

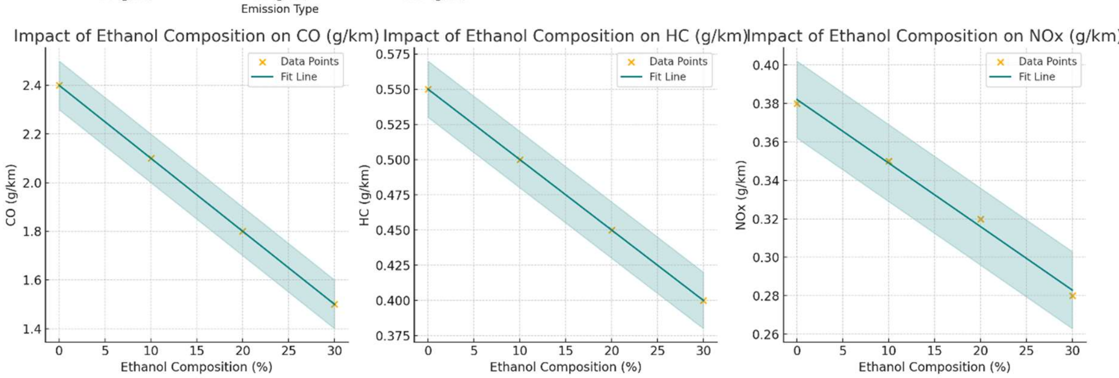

Figure 8 Effect of ethanol composition on Nox

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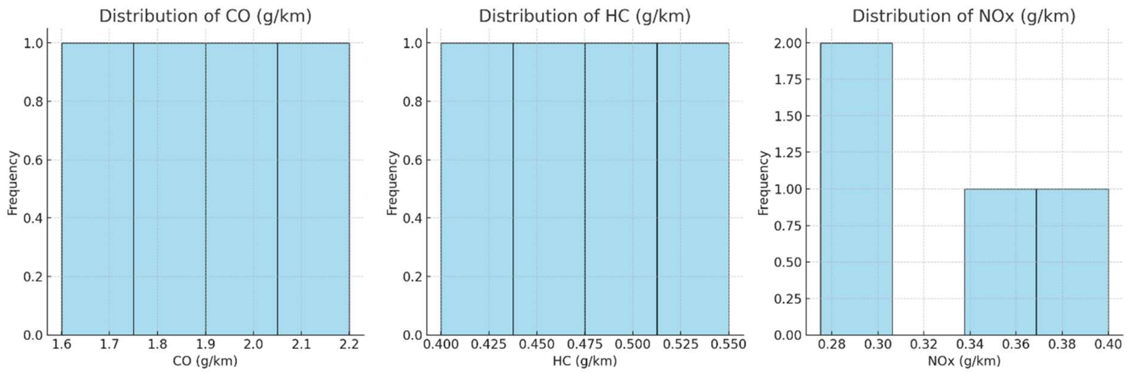

Figure 9 Distribution Of NOx (G/Km)

CONCLUSION

The following conclusions can be drawn from the research conducted on the influence of the composition of ethanol fuel mixture on motor vehicle exhaust emissions in urban conditions:

1. **Reduction of Carbon Monoxide (CO) Emissions**
   - The composition of fuels with a higher ethanol content (E10, E20, E30) significantly reduces carbon monoxide (CO) emissions.
   - At E0 (non-ethanol fuel), CO emissions were recorded at around 2.4 g/km, while at E30 (30% ethanol), emissions dropped to 1.5 g/km.
   - This happens because the oxygen content in ethanol helps in more perfect combustion, thereby reducing CO emissions produced by incomplete combustion.
2. **Reduction of Hydrocarbon (HC) Emissions**
   - Hydrocarbon (HC) emissions have also decreased, although the trend is more subtle compared to CO.
   - At E0, HC emissions reach 0.55 g/km, and at E30 it drops to 0.40 g/km.
   - This decrease is due to a more complete combustion with additional oxygen in the fuel mixture, which reduces the remaining unburned hydrocarbons.
3. **Tren Absorption Nitrogen Oxide (NOx)**
   - Nitrogen oxide (NOx) emissions showed a smaller trend in decline, from 0.38 g/km at E0 to 0.28 g/km at E30.
   - Although the ethanol content can help stabilize combustion temperatures, the impact on the reduction of NOx emissions is relatively small compared to CO and HC.
   - This decrease in NOx needs further attention because NOx emissions are often dependent on combustion temperature and pressure.
4. **Benefits and Challenges**

Benefit:

The use of fuels with higher ethanol content provides environmental benefits through the reduction of greenhouse gas (CO and HC) emissions. This can support better urban air quality and reduce the health risks associated with motor vehicle emissions.

Challenge:

Increased ethanol content can alter combustion characteristics so that it has the potential to increase HC and NOx emissions under certain conditions. Additional emission control technologies are needed to optimize the overall benefits of emission reduction.

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