

The quality of vehicle exhaust gas emission in Sleman, Indonesia in 2019

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Abstract. Human uses vehicles for mobilization from one place to another but there is using vehicle such as exhaust gas emission. This study aimed to identify the quality of vehicle exhaust gas emission in Sleman, Indonesia in 2019. The study was descriptive quantitative research. The data of vehicle exhaust emission and vehicle specification were gathered by means of using gas analyzer, opacity meter, and observation. The data resource was 133 vehicles that use gasoline engine and diesel engine. The data analysis was comparison between the result of testing and regulation of vehicle exhaust gas emission in Special Region of Yogyakarta in 2010. The result of this study showed that rate of amounts of CO, HC, and Particulate Matter in Sleman, Indonesia in 2019 is less than regulation, although there were 13 of 133 vehicles that did not pass the test. Vehicle owners who do not pass the emission test are advised to carry out regular maintenance and use fuel according to ratio of the vehicle compression.

1. Introduction

Human uses vehicles for mobilization from one place to another. For this function, the number of vehicles in a region keep raising every year. This also happens in Sleman Regency, Special Region of Yogyakarta Province, Indonesia. There was an increasing number of motorcycle and car in Sleman Regency with the following details: 781.315 units of vehicle in 2015 and 929.739 units of vehicle in 2016 [1].

Another impact of vehicle usefulness is the presence of vehicle exhaust emission. It contains Carbon monoxide (CO), Particulate Matter, and Hydrocarbons (HC) which are all hazardous to human health. CO can make red blood cells avoid transporting oxygen even lead human to death [2]; [3]. Particulate matter causes brain damage in children [4]. HC is unburnt fuel that causes carcinogenic disease [5]. The percentage of CO in Indonesia has reached 70% and HC has reached 18.43%. Therefore, the danger and high amount of exhaust emission need to be controlled [6].

CO, Hydro Carbon, and Particulate Matters are used as the parameter for quality standard of motorized vehicle exhaust emission [7]. The quality standard of motorized vehicle exhaust emission is maximum limit of substance and pollutant which are launched directly from the exhaust emission system. CO and HC is the parameter of exhaust emission from gasoline-fueled vehicles, meanwhile opacity is the parameter of exhaust emission from diesel-fueled vehicles. The parameter of quality standard of motorized exhaust emission is functioned to determine whether the vehicles pass the exhaust emission test [8].



in Sleman Regency, there are numbers of vehicles do not pass the emission test in every year. In 2013, 34.6% of 104 units of vehicle did not pass the test. In 2014, 25% of 108 units of vehicle did not pass the test. In 2015, 19% of 116 units of vehicle did not pass the test. Based on the problem mentioned previously, the title of this research is: the quality of motorized vehicle exhaust emission in Sleman, Indonesia in 2019 [9].

Vehicles use gasoline engine or diesel engine as the fuel. Gasoline engine vehicle is internal combustion engine which use gasoline as its fuel. To convert the fuel into power, the combustion process is needed. The process of combustion consists of 3 main factors: fuel, oxygen, and fire. There is supporting factors like the pressure of combustion chamber. Diesel engine vehicle is a bit different. It uses oil gas as the fuel. The combustion must have the elements: heat, fuel, and oxygen supported by compression pressure. The combustion process does not use fire but heat because fire cannot burn diesel fuel [10].

The ideal combustion process produces water vapor (H_2O) and carbon dioxide which follows the chemical reaction gasoline + O_2 (in air) $\rightarrow CO_2 + H_2O + \text{heat}$ [11]. The combustion process occurs according to the engine working temperature and composition of stoichiometric air mixture ($\lambda=1$) [12]. However, the ideal condition is difficult because the substance that get into combustion chamber is not only O_2 but also outside air. The combustion process produces heat and exhaust gases. Heat is used to generate power, while vehicle exhaust gases are discharged into the outside air. The composition of vehicle exhaust gases in gasoline engine vehicle consists of 13% H_2O , 14% CO_2 , 71% N_2 , 1% Oxygen and Hydrogen, and 1% pollutants named vehicle exhaust gas emission: CO, HC, and NO_x [13] Whereas in diesel engine vehicle, most of the exhaust gases are particulate matter in the form of dry soot, volatile organic matter, sulfate and ash [14].

2. Research method

This research applied descriptive quantitative approach. The subject research were four-wheeled vehicles or more in Sleman Regency. This research took place in Denggung, Sleman on April 10th, 2019. The testing tools were Four Gas Analyzer and Opacity Meter. The method of testing referred to SNI 19-7118.1-2005 [15] and SNI 19-7118.2-2005. [16] The testing method of vehicle gasoline engine was carried out at idle rotation, while the diesel engine is on a free acceleration cycle. The data analysis technique was carried out by comparing the measurement results with vehicle emission standard as outlined in the Regulation of the Governor of Special Region of Yogyakarta Number 39 (2010). Vehicle emission quality standards are presented in the Table 1.

Table 1. Emission quality standards of four-wheeled vehicles or more.

Categories	Year of Production	Parameter		
		CO (%)	HC (ppm)	PM (% HSU)
Gasoline Motor	< 2007	4,5	1200	-
	≥ 2007	1,5	200	
Diesel Motor				
Gross Vehicle Weight ≤ 3.5 ton	< 2010	-	-	70
	≥ 2010			40
Gross Vehicle Weight > 3.5 ton	< 2010			70
	> 2010			50

3. Results and discussion

Vehicle emission tests conducted on April 10th, 2019 was previously begun with vehicle data collection. The finding showed that the exhaust gas emission of 133 units vehicles were tested. 93 of them were gasoline engine and 40 of them were diesel engine. The brands of the gasoline engine vehicles were

Toyota, Hyundai, KIA, Honda, Daihatsu, Suzuki, Mitsubishi, BMW, Nissan, and Datsun. Meanwhile, the brands of the diesel engine vehicles were Toyota, Mitsubishi Fuso, Isuzu, and Hino.

Gasoline engine vehicles produced in 2007 were 77 units and the ones produced before 2007 were 16 units. Diesel engine vehicles with GVW less than or equal to 3.5 tons which were produced before or in 2007 were 8 units and which were produced after 2007 were 14 units. Diesel engine vehicles with GVW more than 3.5 tons which were produced before or in 2007 were 8 units and which were produced after 2007 were 10 units.

The exhaust emission measurement for gasoline engine vehicles used gas analyzers and for diesel engine vehicle used opacity meter. The result of the measurement, both diesel and gasoline engines, were then averaged by each parameter shown in Table 2.

Table 2. Averages of motorized vehicle exhaust gas emission results.

	Year of production	Parameter		
		CO (%)	HC (ppm)	PM (% HSU)
Gasoline Engine Vehicles	< 2007	1.08	205	-
	≥ 2007	0.12	74	-
Diesel Engine Vehicles	< 2010	-	-	29.63
GVW <3,5 ton	≥ 2010	-	-	31.51
	< 2010	-	-	21.90
GVW <3,5 ton	≥ 2010	-	-	28.89

Gasoline engine vehicles before 2007 produced average CO 1.08% and average HC 205ppm so that the level of CO and HC do not exceed the emission quality standards, which are 4.5% and 1200 ppm. Gasoline engine vehicles in or after 2007 produced average CO 0.12% and average HC 74ppm so that the level of CO and HC do not exceed the emission quality standard which are 1.5% and 200ppm. Thus, it can be concluded that averagely gasoline engine vehicles pass the emission test.

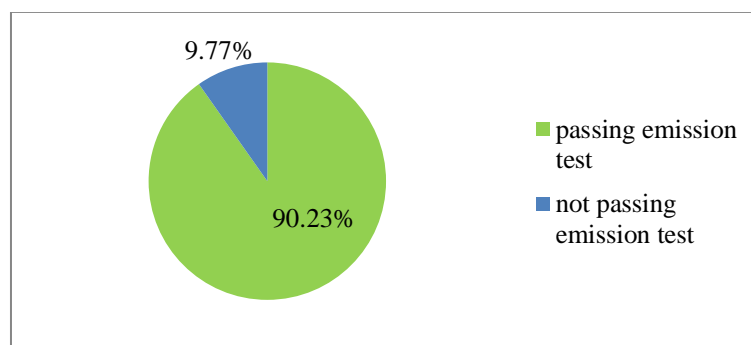
Diesel engine vehicles with GVW less than 3.5 tons which were produced before 2010 had 29.63% particulate matter in their exhaust gas emission so that the level of particulate matter do not exceed the emission quality standard which is 70%. Meanwhile, diesel engine vehicles with GVW less than 3.5 tons which were produced in or after 2010 had 31.51% particulate matter in their exhaust gas emission so that the level of particulate matter do not exceed the emission quality standard which is 40%.

Diesel engine vehicles with GVW more than 3.5 tons which were produced before 2010 had 21.90% particulate matter in their exhaust gas emission so that the level of particulate matter do not exceed the emission quality standard which is 70%. Meanwhile, diesel engine vehicles with GVW more than 3.5 tons which were produced in or after 2010 had 28.89% particulate matter in their exhaust gas emission so that the level of particulate matter do not exceed the emission quality standard which is 50%. Thus, it can be concluded that averagely gasoline engine vehicles pass the emission test.

Although averagely the level of CO, HC, and particulate matter in both gasoline and diesel engines vehicles do not exceed the quality standards, those vehicles needs to be compared one by one with the exhaust gas emission quality standard. The results of measurement on compared exhaust gas emissions showed that there are gasoline and diesel engines vehicle that do not pass the emissions tests. The number of the vehicles that pass and do not pass the emission tests are shown in Table 3.

Table 3. Assessment of result measurement of motorized vehicle exhaust gas emission

	Year of production	Passing Emission Test	Not Passing Emission Test
Gasoline Vehicle	< 2007	74	3
	≥ 2007	15	1
Sub Total		89	4
Diesel Vehicle	< 2010	6	2
GVW <3,5 ton	≥ 2010	10	4
	< 2010	7	1
GVW >3,5 ton	≥ 2010	8	2
Subtotal		31	9
Total		120	13

**Figure 1.** Percentage of result measurement of motorized vehicle exhaust gas emission

There are 13 units out of 133 units of vehicles did not pass the emission tests. It means there are about 9.77%. In 2019, percentage of vehicles that do not pass the emission tests is decreasing when it is compared to the data in 2015 in which there are 19% units of vehicles did not pass the emission tests. The presence of vehicles that do not pass the emission tests is still harmful for human health and environment. Hence, it is important to know why those vehicles failed the tests and how the owners of those vehicles can solve it.

The failure to pass the emission test is caused by the level of CO, HC, and Particulate Matter exceeding the set standard. Untreated HC is caused by fuel that is not burnt in combustion. Unburnt fuel happens when there are influencing factors as follows. (1) Low compression pressure causes the quantity of burning fuel to decrease. The compression pressure determines the amount of compressed air temperature. This temperature is related to fuel evaporation. Low temperature causes fuel difficult to blend with air. As a result, the outcome of combustion still has some fuel. (2) The speed engine that rises suddenly causes the preparation time and combustion of the fuel and air mixture to be shorter. (3) HC concentration increase when the mixture of air and fuel is rich ($\lambda > 1$). It is caused by sparks that are not available long enough to burn the mixture. As a result, there are some fuels that do not burn and get out of the engine into HC. (4) Spark plug sparks too late from specifications 8-5° before TMA. As a result, the mixture that should be burnt is burnt late. The delay in combustion makes some fuels unburnt (Kohler and Allgeier 2015).

There are numbers of factors that affect untreated CO, that are (1) as with untreated HC emissions, the higher process temperatures that accompany high torque foster secondary reactions in CO during the expansion phase, (2) CO emissions also mirror the pattern of HC emissions in their response to variations in engine speed (Kohler and Allgeier 2015), and (3) the mixture of fuel and water affects CO gas. The richer the fuel is burnt, it will produce CO [17].

Untreated Particulate Matter can be seen in vehicle fumes. Good vehicle fumes should not be coloured. If the smoke is white or black, then this indicates that there is a problem with the concentration of exhaust gas. White smoke is thought to be timing injection too late or too early [18]. In diesel engine vehicles, the fuel is not injected at once into the cylinder, but it requires a certain period of time. The duration of injection of this fuel needs to be considered so that no fuel injection occurs after combustion process. If the timing of the injection is late, it will cause the fuel to just evaporate and come out along with the exhaust gas, and the shape becomes white smoke. Whereas, if timing of the injection is too early, it will cause a decrease in compression pressure. It is caused by the heat that partially absorbed by the injected fuel. As a result, the fuel has not been burnt as it is supposed to be and the combustion time is delayed [19].

Black smoke is caused by too rich fuel. The amount of fuel is set by injector or nozzle. Nozzle functions to form fuel fog which is injected into the cylinder or combustion chamber [20]. Broken nozzle causes the rough pressure of fuel fouling shape. The shape of rough fog will make it difficult to evaporate. The fuel that has not evaporated but it has been exposed to high temperature will produce black carbon. In addition to injection timing, the low injection pressure can also cause the presence of particulate matter [21].

From these various caused, appeals are given to the owners of vehicles that do not pass the emission test. This appeal is meant to reduce CO, HC, and Particulate Matter produced by their vehicles. At least, there two ways of reducing emission gas emissions: by regular maintenance and by the use of fuel in accordance to the vehicle compression.

Regular maintenance is meant to maintain the vehicles in their maximum performance. This performance vehicles includes to motorized vehicle exhaust emission. the required roadworthiness is exhaust gas emissions [22]. So, if there is a vehicle exceeding the permitted gas emission limit, then the vehicle is not feasible to operate on the road. For this reason, vehicles need to get regular maintenance by replacing engine oil, clean air cleaner, adjust valve clearance, clean spark plug, adjust injection timing, adjust ignition timing, clean injector, and correct air fuel mixture (Deaton 2006).

Furthermore, the use of fuel that is not in accordance with the vehicle compression will produce exhaust emissions. An owner of Toyota Avanza in 2019 said that he always uses gasoline type *pertalite*. However, the compression ratio is 11,5:1 [23]. The owner should use gasoline type *pertamax* which has RON 92, not *pertalite* which has RON 90. The unmatched values of RON and compression ratio cause the gasoline burnt by the temperature in the cylinder before it ignited by the spark plugs [24]. Likewise, in diesel engine vehicles, lower cetane number means the higher sulfur content in the fuel. Cetane number that is unmatched with the specification causes the increased opacity production [25].

Pertamina, the State Oil and Natural Gas Mining Company, has issued some variants of gasoline and gas oil. They are (1) *pertamax racing* which has RON 100 for vehicles with compression ratio more than 13:1, (2) *pertamax turbo* which has RON 98 for vehicles with compression ratio 11:1 up to 12:1, (3) *pertamax* which has RON 92 for vehicles with compression ratio 10:1 up to 11:1, (4) *pertalite* which has RON 90 for vehicles with compression ratio 9:1 up to 10:1, and (5) *premium* which has RON 88 for vehicles with compression ratio lower than 9:1. While the gas oil variants are: (1) *pertamina dex* which has cetane 53 with sulfur less than 300ppm, (2) *dexlite* which has cetane 51 with maximum sulfur 1200ppm, and (3) diesel oil which has cetane 48 with sulfur 2500 ppm [26].

4. Conclusion

Based on the results of the discussion above, it can be concluded that the quality of motor vehicle exhaust emissions in Sleman, Indonesia in 2019 is below the exhaust gas emission quality standard. However, there are still 13 out of 133 vehicles that did not pass the emissions test. Because there are vehicles that do not pass, the vehicle owner needs to be warned to carry out regular vehicle maintenance and use fuel in accordance with the ratio of vehicle compression.

5. References

- [1] Sleman Central Bureau of Statistics 2017 The Number of registered Vehicles according to the

- types in Sleman Regency expected Military Vehicles in 2015-2016 Online: <https://slemankab.bps.go.id/statictable/2017/11/15/249/jumlah-kendaraan-bermotor-yang-terdaftar-menurut-jenisnya-di-kabupaten-sleman-kecuali-milik-tni-2015-2016.html>
- [2] Ackerman M, Davies T, Jefferson C, Longhurst J and Marquez J 2002 *Advances in Transport Urban Transport VIII: Urban Transport and the Environment in the 21st Century* ed L J Sucharov, C A Brebbia, Francisco, G Benitez and F Benitez (Southampton: WIT Press/Computational Mechanics)
 - [3] Johnson L, Jamriska M, Morawska L and Ferreira L 2000 *Advances in Transport Urban Transport VI: Urban Transport and the Environment in the 21st Century* ed L J Sucharov, C A Brebbia, Francisco, G Benitez and F Benitez (Southampton: WIT Press/Computational Mechanics)
 - [4] Balashanmugam P, Nehrukumar V and Balasubramanian G 2014 A survey on the effects of vehicle emissions on human health in Chidambaram town *Int. J. Eng. Res. Dev.* **10** 24–34
 - [5] Deaton T 2006 *Advanced Automotive Fault Diagnosis* (Oxford: Elsevier Butterworth-Heinemann)
 - [6] Wardhana W A 2004 *Dampak Pencemaran Lingkungan* (Yogyakarta: Andi)
 - [7] Sharaf J, Engineering M T A and Academy B S F 2013 Exhaust Emissions and Its Control Technology for an Internal Combustion Engine *Int. J. Eng. Res. Appl.* **3** 947–60
 - [8] Governor of Yogyakarta Special Region 2010 *Quality Standard of Motorized Vehicle Exhaust Emission in Special Region of Yogyakarta* (Indonesia: BD.2010/NO.39) Online: <https://peraturan.bpk.go.id/Home/Details/27460>
 - [9] Sleman Environment Agency 2015 *Report of Enviroment Status in Special Region of Yogyakarta* (Sleman)
 - [10] Boerlage G D and Broeze J J 1937 The combustion process in the *Chem. Rev.*
 - [11] Heck R M and Farrauto R J 2001 Automobile exhaust catalysts *Appl. Catal. A Gen.* **221** 443–57
 - [12] Hashmi M S J 2014 Introduction to Sensor Materials, Technologies and Applications *Comprehensive Materials Processing* ed M S J Hashmi, G F Batalha, C J V Tyne and B S Yilbas (Amsterdam: Elsevier)
 - [13] Kohler C and Allgeier T 2015 Exhaust emissions *Gasoline Engine Management: Systems and Components* ed K Reif (Wiesbaden: Springer Vieweg) pp 260–7
 - [14] Zhou S, Zhou J and Zhu Y 2019 Chemical composition and size distribution of particulate matters from marine diesel engines with di ff erent fuel oils *Fuel* **235** 972–83 Online: <https://doi.org/10.1016/j.fuel.2018.08.080>
 - [15] National Standardization Agency of Indonesia 2005a *Emisi gas buang - Sumber bergerak - Bagian 1: Cara uji kendaraan bermotor kategori M, N dan O berpengerak penyalan cetus api pada kondisi idle* Online: <http://sispk.bsn.go.id/SNI/DetailSNI/6949>
 - [16] National Standardization Agency of Indonesia 2005b *Emisi gas buang - Sumber bergerak - Bagian 2: Cara uji kendaraan bermotor kategori M, N dan O berpengerak penyalan kompresi pada kondisi akselerasi bebas* Online: <http://sispk.bsn.go.id/SNI/DetailSNI/7104>
 - [17] Arifin Z and Sukoco 2009 *Pengendalian Polusi Kendaraan* (Bandung: Alfabeta)
 - [18] Mohankumar S and Senthilkumar P 2017 Particulate matter formation and its control methodologies for diesel engine : A comprehensive review *Renew. Sustain. Energy Rev.* **80** 1227–38 Online: <http://dx.doi.org/10.1016/j.rser.2017.05.133>
 - [19] The Lecturer Team of Vehicle Diagnosis Subject 2005 *Modul Belajar Diagnosis Kendaraan* Online: <http://staff.uny.ac.id/sites/default/files/pendidikan/joko-sriyanto-spd-mt/modul-diagnosis-kendaraan.pdf>
 - [20] The Lecturer Team of Vehicle Diagnosis Subject 2005 *Modul Belajar Diagnosis Kendaraan* Online: <http://staff.uny.ac.id/sites/default/files/pendidikan/joko-sriyanto-spd-mt/modul-diagnosis-kendaraan.pdf>
 - [21] Arifin Z and Sukoco 2009 *Pengendalian Polusi Kendaraan* (Bandung: Alfabeta)
 - [22] Republic of Indonesia 2009 *Land Traffic and Transport*
 - [23] Toyota Motor Philipines Corporation The Brochure of Toyota Avanza Online:

- http://toyota.com.ph/wp-content/uploads/2018/03/AVANZA-BMC-A4_Feb_Back.pdf
- [24] Ayala F A, Gerty M D and Heywood J B 2018 Effects of Combustion Phasing , Relative Air-fuel Ratio , Compression Ratio , and Load on SI Engine Efficiency Reprinted From : SI Combustion and Direct Injection SI Engine Technology *SAE Tech. Pap. Ser.* Online: <https://www.sae.org/publications/technical-papers/content/2006-01-0229/>
- [25] Cataluna R and Silva R 2012 Effect of Cetane Number on Specific Fuel Consumption and Particulate Matter and Unburned Hydrocarbon Emissions from Diesel Engines *J. Combust.* 2012
- [26] Pertamina BBM Retail Online: www.pertamina.com/id/fuel-retail%0A