Journal of Engineering and Applied Sciences 14 (18): 6703-6709, 2019
ISSN: 1816-949X

Dynamic Model of Sulfur Dioxide (SO_2) and Nitrogen Dioxide (NO_2) Concentration on the Main Road in Makassar City

[1]Anwar Mallongi, [2]Fadly Nur Rahman Umar, [3]Atjo Wahyu, [4]Muh. Saleh, [5]Fatmawati, [6]Abdul Muhith, [7]Herawati, [8]Muhammad Ridwan, [9]A.L. Rantetampang and [9]Yacob Ruru
[1]Department of Environmental Health, Faculty of Public Health, Hasanuddin Universitas, Makassar, Indonesia
[2]Community Training Center of Makassar, Ministry of Village, Undeveloped Regions and Transmigration of the Republic of Indonesia
[3]Department of Occupational Health and Safety, Faculty of Public Health, Hasanuddin University, Makassar, Indonesia
[4]Faculty of Health Sciences, University of Islam Negeri Alauddin, Makassar, Indonesia
[5]Department of Nutrition, Health Polytechnic of Health Ministry, Kendari, Indonesia
[6] Department of Nursing, School of STIKes, Majapahit, Indonesia
[7]Faculty of Public Health, Tompo Tika University, Central Sulawesi, Indonesia
[8]Department Sastra Asia Barat, Fakultas Ilmu Budaya, Universitas of Hasanuddin, Makassar, Indonesia
[9]Faculty of Public Health, Cenderawasih University, Jayapura, Indonesia
anwarmallongi@unhas.ac.id : anwar_envi@yahoo.com

Abstract: The amount of exhaust emissions resulting from the burning of motor vehicles caused the air in the city of Makassar to be polluted. This study aims to estimate the concentration of Sulfur dioxide (SO_2) and Nitrogen dioxide (NO_2) for 10 years (2017-2027) on the main road of Makassar city. This research is an observational analytic research with dynamic system model approach. Results showed that in the next 10 years, the estimated total concentration of total Sulfur dioxide (SO_2) in the first scenario without do nothing in 2017 of 6.44 $\mu g/Nm^3$ increased by 2027 by 8,581 $\mu g/Nm^3$ by multiples of increased concentration 61.58 times/month and an annual increase of 1.80 times/year whereas the estimated concentration of Nitrogen dioxide (NO_2) in the absence of control measures increased from 2017 by 4.99 $\mu g/Nm^3$ increased by 2027 by 7,934 $\mu g/Nm^3$ by multiples of increased concentration 37.6 times/month. Application of Second Scenario (2) has decreased total concentration of Sulfur dioxide (SO_2) and Nitrogen dioxide (NO_2) when compared to total concentration in first scenario (I). Increasing the concentration of Sulfur dioxide (SO_2) in 2017 by 6.44 $\mu g/Nm^3$ increased by 2027 by 3785 $\mu g/Nm^3$ with total monthly concentration increase of 37.4 times/months and total annual concentration increase of 0.72 times/year. Effectiveness in the second scenario in reducing the concentration of Nitrogen dioxide (NO_2) by 22.72%. Application of the third scenario (3) there is a significant decrease in the concentration of sulfur dioxide and nitrogen dioxide when compared to the first scenario (1). Effectiveness in the third scenario (3) in reducing sulfur dioxide concentration of 66.43%. Implementation of the fourth scenario (4) passenger shift for the use of bus rapid transportation (bus rapid transportation) with the aim of decreasing the volume of vehicles operating on the main road, if it is assumed that 50% of passengers switch to BRT bus, BRT passengers in 2027 will be 3960/days.

Key words: Estimation, dynamic model, sulfur dioxide, nitrogen dioxide, bus rapid, implementation

INTRODUCTION

Air is one of the most important necessities for the survival of living beings. Most sources of air pollutants come from anthropogenic sources. The gases are Carbon monoxide (CO), Hydrocarbon (HC), Nitrogen Oxide (NO_2), Sulfur compounds (H_2S and SO_2) and Ozone (O_3). Motor vehicles issue various types of gases or harmful particulates derived from the burning of fuel on vehicle engines that can cause negative impacts, both on human health and on the environment.

Corresponding Author: Anwar Mallongi, Department of Environmental Health, Faculty of Public Health, Hasanuddin Universitas, Makassar, Indonesia, anwarmallongi@unhas.ac.id: anwar_envi@yahoo.com

Environmental changes are influenced by two factors: natural factors and factors of human activity. The influx of natural pollutants such as forest fire fumes, volcanic eruptions, meteorite dust and salt emissions from the sea while factors caused by human activities such as transportation activities industrial development, garbage disposal (Soedomo, 2001).

According to Soedomo by Tugaswati, the increased volume of vehicles on roads with fixed road capacity and accompanied by frequent stopping road patterns will also directly affect the amount of emissions of motor vehicle exhaust generated and contribute to ambient air quality at the site . In addition, the types and characteristics of machine tools, combustion systems and fuel types are also factors that will determine the level of pollution emissions of each type of vehicle.

Jakarta as the capital of the Republic of Indonesia is highly dependent on petroleum fuels such as gasoline, diesel and soybean which account for 68% of total energy consumption. The economic increase and the density of inhabitants entering the city are directly related to the level of air pollution and in the third rank in the world with the worst air quality where the 70% pollution rate is caused by the active transport.

Estimating the events and impacts of future air pollution is an important aspect of community health planning. At present, there are several studies on the dynamic model used to predict or estimate various air pollutants in the next few years. Testing model and policy analysis explain the test procedure of the scientific truth of the model, i.e., to what extent the model can be accounted for in analysis by a problem solving.

In 2013, the Regional Environment Agency (BHLD) of South Sulawesi Province measured ambient air quality at fifteen dots on the highway. Parameters measured were Sulfur dioxide (SO_2), Nitrogen dioxide (NO_2), Carbon monoxide (CO), Ozone (O_3), Tin (Pb) and particulate. For SO_2 and NO_2 measurements at fifteen points showed SO_2 values ranging from 21.5-43.52 μg/Nm^3. While for the measurement of NO_2 at fifteen points ranged from 27.92-55.86 μg/Nm^3. The results of measurements at all locations also indicate that at the front site of the Governor's Office, front of the Wirabuana Kodam Meeting Hall and the front door II of KIMA is the most prominent parameter value compared to other locations.

This study aims to estimate the concentration of Sulfur dioxide (SO_2) and Nitrogen dioxide (NO_2) gas by using dynamic model approach in the next 10 years (2017-2027) on the main road of Makassar city.

MATERIALS AND METHODS

Research methods: This research is an observational analytic research using dynamic system model approach, i.e., data collection to design a model that aims to describe and predict the future of air quality in five streets of Makassar city.

Research sites: This research was conducted for 5 months i.e., from April to August 2017 in five main streets in Makassar city which is on Jalan Perintis Kemerdekaan, Jalan Dr. Ratulangi, Jl. Ahmad Yani, T-junction Jl. Pettarani and Jl. Alauddin, Jl. UripSumoharjo.

Population and sample: The population in this study is the air that is on the main road of Makassar city. The air samples to be studied are ambient air in the five roads of Makassar city. The sampling technique used in this research is purposive sampling which based on the consideration of data from the previous research result indicating that the sampling point location is the most prominent location of Sulfur dioxide (SO_2) and Nitrogen dioxide (NO_2) parameter and also, includes the location of congestion point in Makassar city. Air sampling is conducted on the roadside, the sampling point is 1-5 m from the edge of the highway with a height of 1.5-3 m.

Data collection: Air samples taken directly in five streets of Makassar city with the help of BTKL-PP Makassar. Primary data obtained from the measurement of SO_2 and NO_2 content in ambient air and then performed in laboratory examination. Secondary data obtained from Environment Agency of Makassar city region in the form of measurement result report of ambient air quality test.

Data analysis: Data analysis is dynamic system analysis using Stella program. Time and number of simulations performed are 10 years (2017-2027) using four scenario approaches, first scenario (1) simulation without any policy or regulation to suppress the rate of SO_2 and NO_2 (do nothing) concentration increase, second scenario 2) the application of policies of the use of premium type of fuel to pertamax type fuel, The third scenario (3) is the application of the policy of application of vehicle life restriction.

RESULTS AND DISCUSSION

First scenario (do nothing): Figure 1 shows that the increase in SO_2 concentration in the next 10 years is

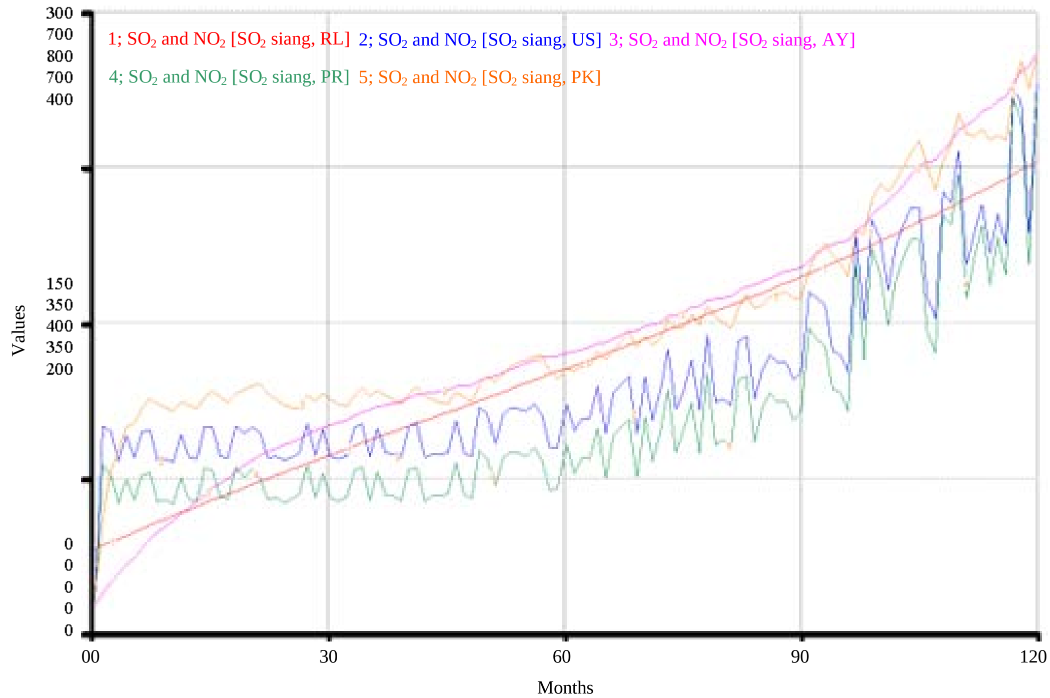

Fig. 1: Estimated concentration of Sulfur dioxide (SO_2) in the next 10 years (2017-2027) in five streets of Makassar city based on the first scenario (1)

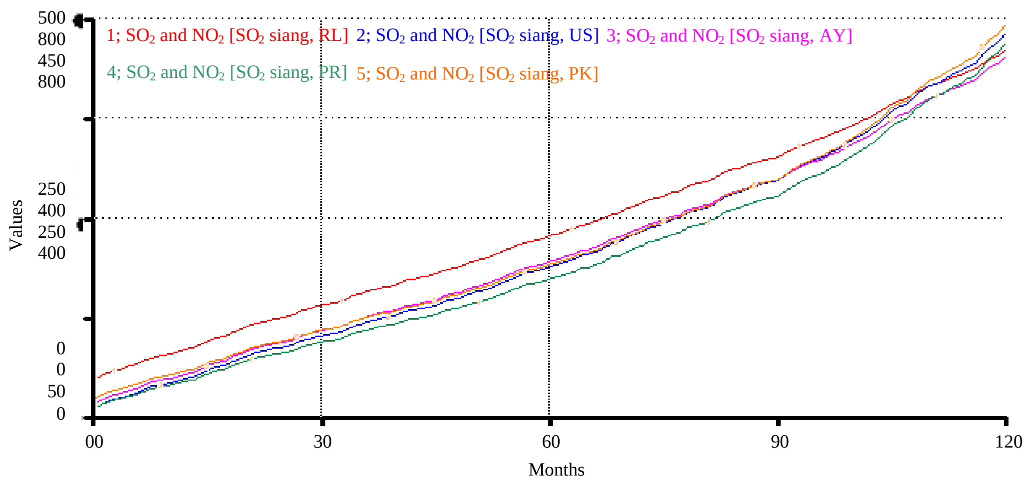

Fig. 2: Estimation of Nitrogen dioxide (NO_2) concentration in the next 10 years (2017-2027) in five streets of Makassar city based on the first scenario (1)

2017-2027 Sulfur dioxide (SO_2) concentration in five streets of Makassar city with total of 645 μg/Nm^3 in 2017 increased in 2027-8581 μg/Nm^3 with increasing monthly at 61.58 times and an annual increase of 1.80 times.

Figure 2 and 3 shows that the concentration of Nitrogen dioxide (NO_2) in the next 10 years (2017-2027) in five streets of Makassar city increased monthly average by 37.6 times/months, total concentration of Nitrogen dioxide concentration NO_2) of 499 μg/Nm^3 in 2017 and increased by 2027 by 7934 μg/Nm^3 with an annual increase of 2.27 times.

Second scenario (2): This scenario is the implementation of the scenario of the replacement of the use of premium fuel to pertamax fuel for vehicles operating on the main roads of Makassar city. The results of the second

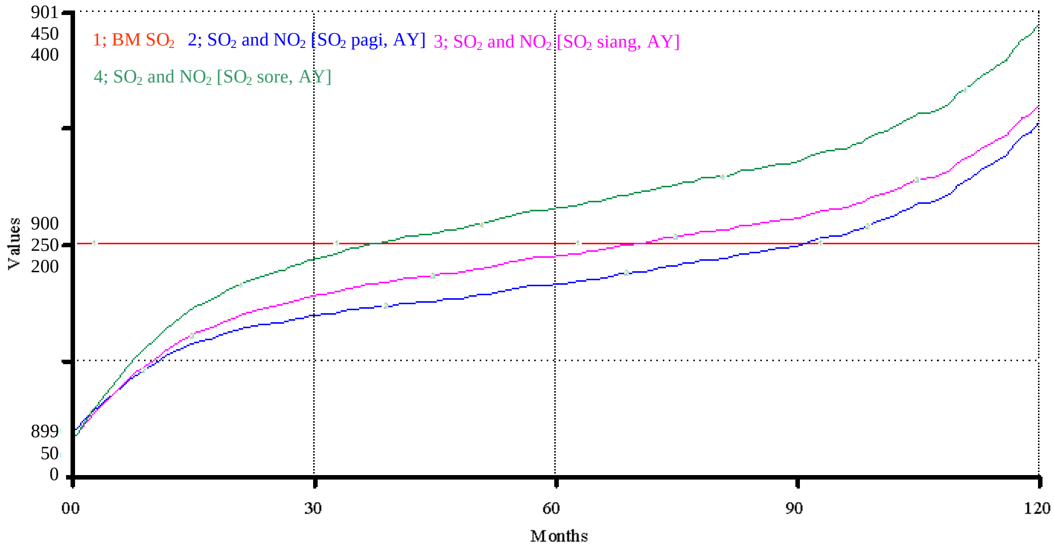

Fig. 3: The estimated concentration of Sulfur dioxide (SO_2) at Ahmad Yani Street in the morning, afternoon and afternoon is associated with the quality standard set for Sulfur dioxide (SO_2) in Ahmad Yani Kota Makassar in the next 10 years (2017-2027) based on the second scenario (2)

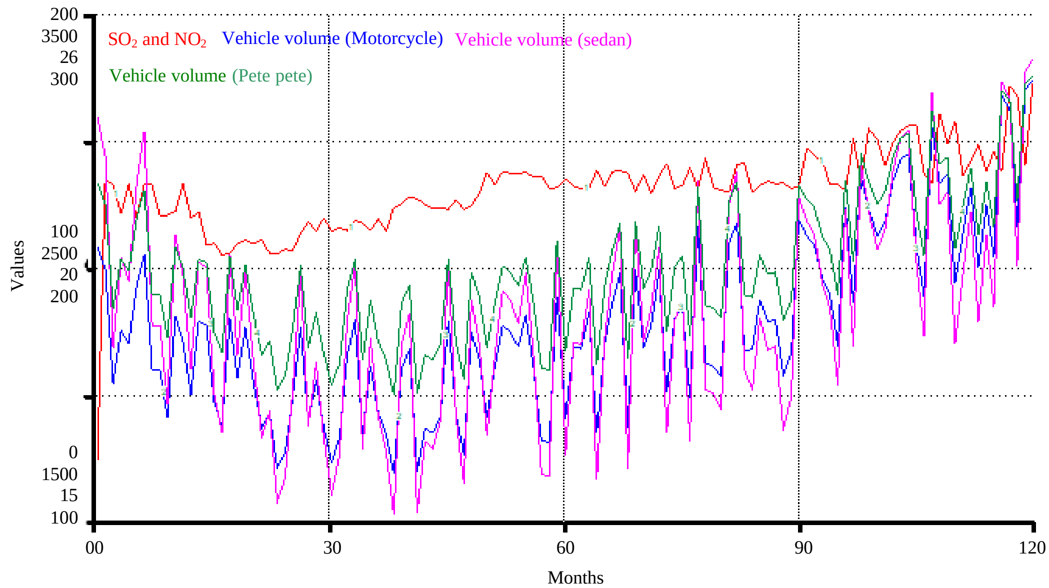

Fig. 4: Estimation of Sulfur dioxide (SO_2) concentration at Jalan Urip Sumoharjo in the morning is connected with volume motor vehicle, sedan, petepete and truck at UripSumoharjo Makassar city in the next 10 years (2017-2027) based on (3) scenario.

scenario (2) i.e., the concentration of Sulfur dioxide (SO_2) in the next 10 years (2017-2027) in the five streets of Makassar city decreased the concentration when compared with the results of the simulation in the first scenario (1). The total concentration of Sulfur dioxide (SO_2) of 499 μg/Nm^3 in 2017 increased in 2027 to 3785 μg/Nm^3 in scenario 2 when compared to scenario 1 there was a decrease in total concentration of 4799 μg/Nm^3. Percentage increase per year by 0.72 fold and with monthly average increase equal to 37.4 times. From the results of the second scenario (2) its effectiveness of 47.96% in reducing the concentration of Sulfur dioxide (SO_2) (Fig. 4).

The results of the (2) scenarios for the concentration of Nitrogen dioxide (NO_2) in the next 10 years (2017-2027) in the five streets of Makassar city also, decreased when

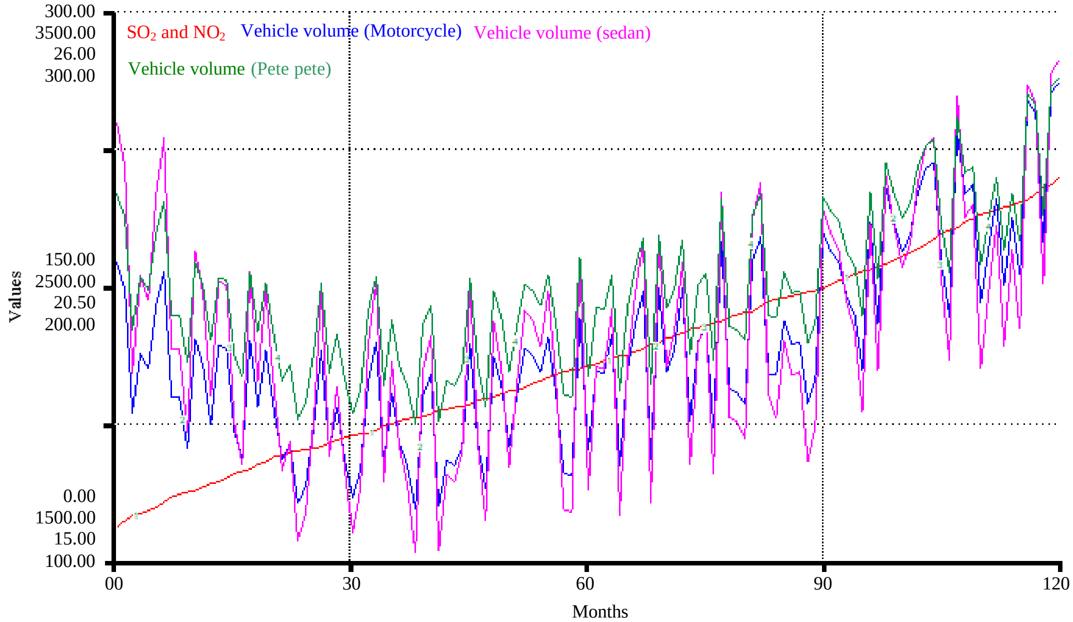

Fig. 5: Estimation of Nitrogen dioxide (NO_2) concentration at Jalan Urip Sumoharjo in the morning is attributed to the density of motor vehicles, sedans, petepete and trucks at Urip Sumoharjo Makassar city in the next 10 years (2017-2027) based on third (3) scenario

compared with the results of the simulation in the first scenario (1). Concentrations experienced an annual increase of 1.64 times of total Nitrogen dioxide (NO_2) 499 μg/Nm^3 by 2017 and decreased in the 10th year on a scenario simulation to 5662 μg/Nm^3 with a monthly increase of 31.7 times. From the results of the scenario (2) the effectiveness of 22.72% in reducing the concentration of Nitrogen dioxide (NO_2).

Third scenario (3): Third (3) scenario is an application of vehicle age restrictions that operate on the main road of Makassar city the results of the (3) scenario for the concentration of Sulfur dioxide (SO_2) in the next 10 years (2017-2027) in the five streets of Makassar city decreased the concentration when compared with the results of the simulation in the first scenario (1). Total concentration of Sulfur dioxide (SO_2) of 645 μg/Nm^3 in 2017 increased in 2027-1938 μg/Nm^3 in scenario 3, compared to scenario 1, it decreased total concentration of 6643 μg/Nm^3. Percentage increase per year by 0.30 times and with an average monthly increase of 22.5 fold. Based on the result of simulation of scenario (3) its affectivity equal to 66.43% in reducing concentration of Sulfur dioxide (SO_2).

The results of the (3) scenario for the concentration of Nitrogen dioxide (NO_2) within the next 10 years (2017-2027) in five streets of Makassar city also, decreased when compared with the results of the simulation in the scenario (1). Concentrations experienced an annual increase of 0.86 times of total Nitrogen dioxide (NO_2) 499 μg/Nm^3 by 2017 and increased in the 10th year in scenario simulations to 3182 μg/Nm^3 with monthly increase of 24.3 times. Based on the result of simulation the scenario (3) its effectiveness equal to 47,52% in reducing the concentration of Nitrogen dioxide (NO_2) (Fig. 5).

This study shows that the estimated concentrations of Sulfur dioxide (SO_2) and Nitrogen dioxide (NO_2) exceed the quality standards set by the government in 10 years (2017-2027) that will come on several main roads in Makassar. Based on South Sulawesi Governor Regulation No. 69/2010 on Quality Standard And Environmental Damage Criteria, the ambient air quality standard for SO_2 parameters has a threshold of 900 μg/Nm^3 and 400 μg/Nm^3 for NO_2 parameters. Some factors or variables that affect it are the type of vehicle, vehicle density, vehicle volume, fuel type, fuel consumption, vehicle emissions and meteorological factors at the study sites.

Based on research conducted by Hodijah, the contribution of SO_2 gas pollutants in Jalan Sudirman is dominated by various types of vehicles. Percentage of SO_2 gas pollutant load in Jalan Sudirman from truck type 26.7, van/sedan 23.4, motorcycle 22, bus 17.5% and the rest are public transport and pickup type vehicles. This is supported by the opinion Susilawaty and La Ane, that the high rate of rapid transportation development affect air quality, especially, air quality in the city of Makassar.

The current concentration of SO_2 and NO_2 at each point or location is still below the threshold set by the government. This is in line with research conducted by Maulana (2012) that air pollution caused by emission sources moved in Magelang Street D.I. Yogyakarta showed SO_2 measurement result of 58.1 μg/m^3, NO_2 concentration of 69.76 μg/m^3. The results of this study did not vary much with the research conducted by Sari and Driejana which obtained the value of NO_2 concentration on the roadside in the Karees Region, Bandung is in the range 27.6 - 56.3 μg/m^3.

The 1 scenario is without any intervention of policy or regulation (do nothing) i.e., the current rill condition, then simulated for 10 years to come. The concentration values of SO_2 and NO_2 concentrations are influenced by various factors, especially, from transportation activities such as the number of vehicles. Increasing number of vehicles, affecting vehicle density and increasing exhaust emissions resulting in ambient air pollution. This scenario only looks at the current problems with the condition that various air pollution control measures are not working properly.

The scenario (2) is the application of the policy of using premium fuel to pertamax fuel, then simulated for 10 years to come (2017-2028). Fuel consumption is increasing and the type of fuel used will affect the amount of emissions of vehicles that come out. Another study suggests that the octane value in the fuel used will affect the characteristics of exhaust emissions generated into ambient air. Another study related to the composition of the premium fuel is a clear yellow distillate fuel type. Gasoline has good anti-tapping properties and can be used on machines with 9.0: 1 compression capacity in all types and conditions. Pertamina's premium gasoline has maximum sulfur content of 0.05%, Lead (Pb) 0.013% (unleaded type) and lead (Pb) 0.3% (lead type) Oxygen (O) 2.72% , dye 0.13 g/100 L, vapor pressure 62 kPa, boiling point 215°C and mass temperature (15°C) 715-780 kg/m^3). While pertamax fuel is a type of fuel with an octane value of 92 has no lead in it so, as to reduce toxic exhaust gas vehicles such as Nitrogen Oxide (NOx). First type fuel has maximum Sulfur (S) content of 0.1, 0.013% lead (leadless type) and lead 0.3% (lead type), Oxygen (O) 2.72%), 0.13% dye g/100 L, vapor pressure 45-60 kPa, boiling point 205°C and temperature of temperature type (temperature 15°C) 715-780 kg/m^3 (Mallongi *et al*., 2017; Nur *et al*., 2019).

The scenario (3) is the application of vehicle age restriction policies that operate on the main road of Makassar city. The age limit of vehicles in this scenario is a vehicle with an age of 10 years. This vehicle means vehicle category or vehicle that will be restricted to operate on the highway that will be simulated in the model.

According to research conducted obtained the result that emissions of CO, HC and NOx will increase with age of vehicle. Research on vehicle emissions test of Honda Vario motor matic, age mesih will affect the amount of emitted emission. The increasing age of the vehicle means the performance of the engine will be heavier, so that, the condition of the engine is not in good condition. Emissions generated, if the service is not done periodically will further increase vehicle emissions.

Another study conducted by Winarno and Malhjlongi *et al*. (2019) that the performance of new vehicle engines generally have lower exhaust emissions compared with older vehicles, especially, in concentrations of CO, NO_2 and HC. In contrast to the results of the study, the result shows that new vehicles in 2013 have NOx concentrations higher than those of 2009 vehicles. The NOx concentrations in vehicles in 2013 amounted to 382 ppm and NOx concentrations in vehicles in 2009 of 363 ppm.

Air quality monitoring should continue to be implemented because it can have an impact on the environment and public health. Several studies have shown that throat irritation occurs at SO_2 levels of 5 ppm or more. Individuals with symptoms of the disease are very sensitive to contact with SO_2, albeit at relatively low levels. According to Soemirat, the health effects caused by lethal concentrations of Nitrogen dioxide (NO_2) exposure are at concentrations of 150-200 ppm which will cause "Bronchiolities fibrosa obliterons" and fatalities will cause death after exposure 2-10 days when exposed to the concentration of Nitrogen dioxide (NO_2) was >500 ppm.

CONCLUSION

Estimated concentration of Sulfur dioxide (SO_2) and Nitrogen dioxide (NO_2) in five main streets of Makassar city for the next 10 years with the first scenario do nothing i.e., without any effort in suppressing the rate of gas emission gas concentration. The concentration of Sulfur dioxide (SO_2) was 8.581 μg/Nm^3 while the concentration of Nitrogen dioxide (NO_2) was 7.934 μg/Nm^3 with monthly increase of 0.07 times/month.

Estimated concentration of Sulfur dioxide (SO_2) and Nitrogen dioxide (NO_2) in five main streets of Makassar city over the next 10 years under scenario (2) implementation of the policy of using premium fuel to fuel pertamax type. The concentration of Sulfur dioxide (SO_2) decreased when compared with the scenario (1) of 3785 $\mu g/Nm^3$ while the concentration of Nitrogen dioxide (NO_2) also, decreased by 5662 $\mu g/Nm^3$. In the scenario (2) the effectiveness in reducing the concentration of Sulfur dioxide (SO_2) is 47.96% while the effectivity in reducing Nitrogen dioxide (NO_2) is 22.72%.

Estimated concentration of Sulfur dioxide (SO_2) and Nitrogen dioxide (NO_2) in five main streets of Makassar city for 10 years to come with scenario (3) which is limitation of vehicle age which operates in main road of Makassar city. In this scenario Sulfur dioxide concentrations decreased significantly from 1938 $\mu g/Nm^3$ when compared to scenario (1) of 8581 $\mu g/Nm^3$. It also, decreased the concentration of Nitrogen dioxide (NO_2) by 6643 $\mu g/Nm^3$ when compared with scenario (1) the amount of Nitrogen dioxide concentration was 7934 $\mu g/Nm^3$. The effectivity in reducing the concentration of Sulfur dioxide (SO_2) is 66.43% while the effectivity in reducing the concentration of Nitrogen dioxide (NO_2) is 47.52%.

RECOMMENDATIONS

Based on the results of the study, it may be advisable to conduct further research by including data related to the reduction of air pollutant concentrations including the ability of tree uptake or green open space (RTH), the amount of concentration absorbed into the ground and carried by the wind.

ACKNOWLEDGEMENT

Researchers are grateful to Makassar Municipality, South Sulawesi Province for providing permission of this research as well as the local community who were very kind to assist us in providing some necessary information and allowing us to collect some samples. Researchers also would like to thank to the director of Hasanuddin University who have given a part of funding support during the commencement this study and thank to Chemical Laboratory of Accredited Labkes Makassar for conducting the analyses in accordingly.

REFERENCES

Malhjlongi, A., D. Safiu, H. Amqam, A. Syam and M. Hatta *et al*., 2019. Modelling of SO_2 and CO pollution due to industry PLTD emission Tello in 2 Makassar Indonesia. J. Eng. Appl. Sci., 14: 634-640.

Mallongi, A., R. La Ane and A.B. Birawida, 2017. Ecological risks of contaminated lead and the potential health risks among school children in Makassar coastal area, Indonesia. J. Environ. Sci. Technol., 10: 283-289.

Maulana, A.Z., 2012. Analisys of air polluter SO_2, NO_2 and HC by using line source modeling approach (case study at Jalan Magelang Yogyakarta). Widyariset, 15: 499-508.

Nur, R., A. Mallongi, I.P.K. Demak, Fadliah and E.B. Yane *et al*., 2019. Early-age marriage and the impact of health reproduction women. J. Eng. Appl. Sci., 14: 981-986.

Soedomo, M., 2001. [Air Pollution]. ITB Press, Bandung, Indonesia, (In Malay).