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Dynamic Modeling of Sulfur Dioxide and Ozone Pollutants at Makassar Main Road Indonesia

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Abstract: This research aims to estimate the concentration of Sulfur dioxide (SO_2) and Ozone (O_3) in the next 10 years on the main roads of Makassar and evaluated effectiveness the model concentration of Sulfur dioxide (SO_2) and Ozone (O_3). This research used an observational descriptive study with system dynamic models. The research was conducted on eight main roads at Makassar city with using purposive sampling method. Data analysis was the analysis of dynamic system using the program Stella. Dynamic modeling was started with flowchart model. The results showed that in 10 years from now, the estimated concentration of Sulfur dioxide (SO_2) in the absence of control measures increased by 6286 mg/Nm^3 with a multiple increase in concentration of 0.03 times/month whereas the estimated concentrations of Ozone (O_3) in the absence of control measures increased by 4358 mg/Nm^3 with a multiple increase in the concentration of 0.15 times/month. An increase in the estimated rate of SO_2 and O_3 concentrations can be reduced through policy intervention to a concentration of SO_2 fell by 2675 mg/Nm^3 with an increase of 0.1 fold and O_3 concentration decreased by 1815 mg/Nm^3 with an increase of 0.06 times/month. The most appropriate in reducing the rate of increase in the concentration of SO_2 and O_3 is the combined simulation (scenario 2-4).

Key words: Estimation, dynamic model, sulfur dioxide, ozone, reducing, concentration

INTRODUCTION

Air is a very important requirement for the survival of living beings. The composition of the air normally consists of a mixture of various gases are Nitrogen gas (N_2), Oxygen (O_2), Carbon dioxide (CO_2) and the rest is a noble gas. However, increasing the physical development of cities and industrial centers as well as a surge in the production of motor vehicles in various parts of the world, causing air quality change. Source largest producer of air pollutants originating from anthropogenic sources. These gases are Carbon monoxide (CO), Hydrocarbons (HC), Nitrogen Oxide (NO_2), Sulfur compounds (H_2S and SO_2) and Ozone (O_3) (Soedarto, 2013). With increasing number of vehicles this time, the greater the air pollution caused. Approximately, 70% contribution of air pollution originating from the transport sector, especially, for sources coming from the highway, the largest contribution was donated by the combustion of exhaust fumes of motor vehicles (Hidup, 2009). Air pollution has a negative impact on human health such as respiratory problems, coughs, bronchitis and lung (Adisasmita and Adisasmita, 2011). Further, it is said that the reduced levels of air pollution would also lower the demand for hospital care, since, hospitalizations would diminish (Abe and Miraglia, 2016). Estimate the incidence and impact of the air pollution in the future, an important aspect of public health planning. At this time, there are few studies on the dynamic models are used to predict or estimate a variety of air pollutants the next few years. Testing models and policy analysis to explain the scientific validity of test procedures models, namely the extent to which the model can be accounted for in the analysis by a problem solving (Siswosudarmo, 2001).

Triggered by air pollution problems are getting more serious, the Chinese Government made a series of policies to prevent and control air pollution by establishing a system dynamic model. PM10 concentrations will fall by more than 10% in 2017 compared to 2012 while SO_2. decreased during the simulation period 2013-2022 which has been completed in accordance with the relevant data. This analysis can help companies of coal and power companies conduct strategic environmental assessment and finding the direction of sustainable development (Guo *et al*., 2015). All of the sulfur-containing primers

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significantly improved the resin bond strength as compared to that of the non-primed group at TC_0 regardless of the metal type p< 0.05 (Yoshida, 2017). In the city of surabaya, several studies using dynamic models to make efforts to control the concentration of air pollutants through increased absorption of pollutants by green open space (RTH) and to optimize the broad shade trees. Efforts to increase the absorptive capacity of the tree to the total CO_2 can increase the absorption of 2456.04-5580.28 tons/years in the North and the Surabaya area of 9885.48-13384.76 tons/years in the area of East Surabaya (Pradiptiyas, 2010). In 2013, the Regional Environmental Agency (BHLD) South Sulawesi measuring ambient air quality in the fifteen points on the highway. Parameters measured were Sulfur dioxide (SO_2), Nitrogen dioxide (NO_2), Carbon monoxide (CO), Ozone (O_3), lead (Pb) and particulate. For the measurement of SO_2 and O_3 on a fifteen point indicates the value of SO_2 ranges from 21.55 mg/Nm^3 up to 43.52 g/Nm^3. As for the results of measurements of O_3 at fifteen point range 20.31 mg/Nm^3 up to 74.73 g/Nm^3. It also found that the change in emissions in each pollutant is a result of the more stringent control of fuel and engine standards, the shift in the fuel type used and the effects of controlling some emissions (Cheewaphongphan *et al*., 2017). Results of measurements at all locations also show that in front of the location of the governor's office, meeting hall Wirabuana front and the front doors II KIMA most prominent parameter value compared to other locations (Zakaria, 2013). This study aims to estimate the ambient air quality, especially, Sulfur dioxide gas (SO_2) and Ozone (O_3) by using a dynamic model on the main roads of Makassar.

MATERIALS AND METHODS

Research methods: This research is an observational analytic study using a dynamic system modeling approaches, namely data collection to design a model that aims to describe and forecast the future of air quality in some streets of Makassar.

Research sites: This study was conducted over 2 months ie from April-May 2015 in eight major roads in the city of Makassar, namely) Front door II KIMA (Independence Pioneer Road). Future Governor's Office (Jl. Urip Sumoharjo). The front office PLN Region VII Sulawesi (Jl. Hertasning). A street intersection Pengeran Pettarani with the Sultan Alauddin Home Hotel Bumi Asih Jaya (Jl. Dr. Ratulangi). Side Karebosi Link (Jalan Ahmad Yani). Home stadium Mattoangin (Jalan Cendrawasih). The front of house mayoralty (Jl. Comforter). Population and sample. The population in this study is the air that is in the main street of the city of Makassar. Air samples to be studied is the ambient air in eight road Makassar. The sampling technique in this research is purposive sampling based on account data from previous research, indicate that dot sampling site is the location of the most prominent parameter values Sulfur dioxide (SO_2) and Ozone (O_3) and includes the location of congestion points in the city of Makassar. Air sampling conducted by the roadside (roadside), the point of sampling within 1-5 m from the edge of the highway with a height of 1.5-3 m.

Data collection: Air samples taken directly in 8 street Makassar with the assistance of BTKL-PP Makassar. Primary data obtained from the measurements of the content of SO_2 and O_3 in ambient air and then examined in a laboratory. Secondary data were obtained from the Regional Environmental Agency of Makassar in the form of a report measurement results of ambient air quality testing (Table 1).

Data analysis: Data analysis is the analysis of dynamic systems using Stella Program. Timing and amount of the simulation is for 10 years (2015-2025) with a total of 5 types of simulation.

Table 1: Ambient air quality in Makassar

Road names	Wind speed (m/sec)	Temp. (°C)	Humidity (% rh)	SO_2 (μg/Nm^3)	O_3 (μg/Nm^3)	NO_2(μg/Nm^3)
DR. Ratulangi	0.00-1.83	33.0	58.3	86.46	49.07	62.90
Penghibur	0.34-2.76	33.2	60.4	59.66	26.58	54.56
Urip Sumoharjo	0.00-0.95	29.5	64.4	101.21	18.11	50.68
Ahmad Yani	0.99-3.36	31.3	60.1	71.79	42.67	61.10
AP Pettarani	0.05-1.14	33.3	61.1	84.49	22.75	33.93
Hertasning	0.04-0.39	26.9	74.7	79.37	19.25	34.58
Cendrawasih	0.04-0.58	35.3	44.3	58.79	42.30	56.87
Perintis Kemerdekaan	0.28-1.60	32.4	59.3	66.99	53.92	59.21

RESULTS AND DISCUSSION

Results of this research shows that estimates of SO_2 and O_3 concentration decreased in scenario 2-5 application on the main roads of Makassar 10 years to come (2015-2025). Scenario V is the scenario that is most effective in reducing the rate of increase in the concentration of SO_2 and O_3. Concentration of Sulfur dioxide (SO_2) and Ozone (O_3)

Scenario 1: Figure 1 and 2 show the results of the estimation of concentration of SO_2 and O_3 in the 10 years to come (2015-2025) on the main roads of Makassar on the simulation without SO_2 increased total concentration of 3.50 times that of the total concentration of the existence of a policy action or regulation.

Figure 1 shows the predicted estimate SO_2 concentration of 1797 mg/Nm^3 in 2015 increased to 6286 mg/Nm^3 in 2025 with an increase every month was 0.03 times. Figure 2 shows the predicted estimate of O_3 concentration increased by 17.61 times that of the total O_3 concentration of 245 mg/Nm^3 in 2015 increased to 4358 mg/Nm^3 in 2025 with an average monthly increase was 0.15 times.

Scenario 2: Figure 3 and 4 show the results of the estimation of concentration of SO_2 and O_3 in the 10 years to come (2015-2025) on the main roads of Makassar with scenarios restrictions on the age of the vehicle. Figure 4 shows the estimated experienced decrease O_3 concentration of 4358 mg/Nm^3 be 3463 mg/Nm^3 in 2025, the average monthly increase in the concentration of 0.15 times down to 0.12 times.

Scenario 3: Figure 5 and 6 show the results of the estimation of concentration of SO_2 and O_3 in the 10 years to come (2015-2025) on the main roads of Makassar with fuel usage policy scenarios. Figure 5 shows the estimated

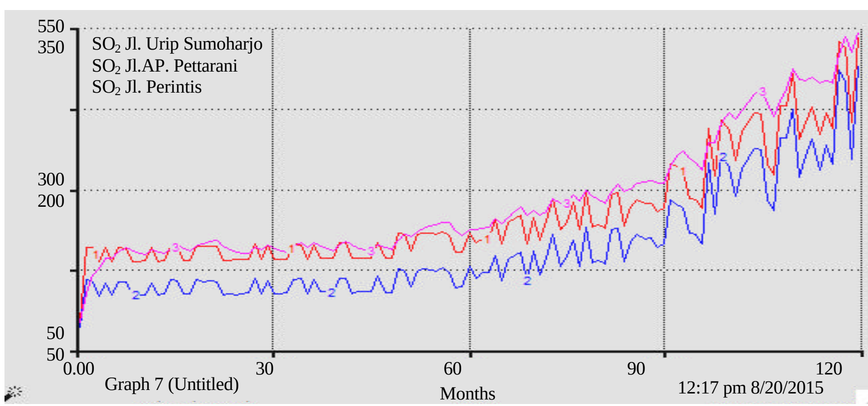

Fig. 1: Estimated SO_2 concentrations in 10 years to come (2015-2025) in Jl. Urip Sumoharjo, AP Pettarani and Jl. Perintis Kemerdekaan based first scenario

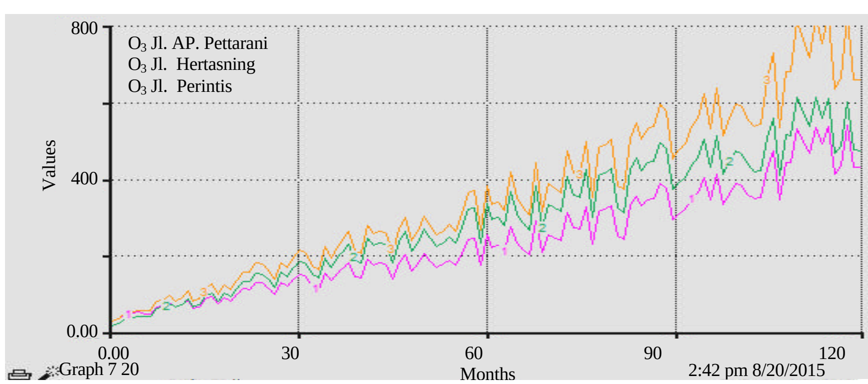

Fig. 2: Estimated concentrations of O_3 in 10 years to come (2015-2025) in Jl. Urip Sumoharjo, Jl. AP.Pettarani, Jl. Hertasning, Jl. Cendrawasih and Jl. Perintis Kemerdekaan based on the first scenario

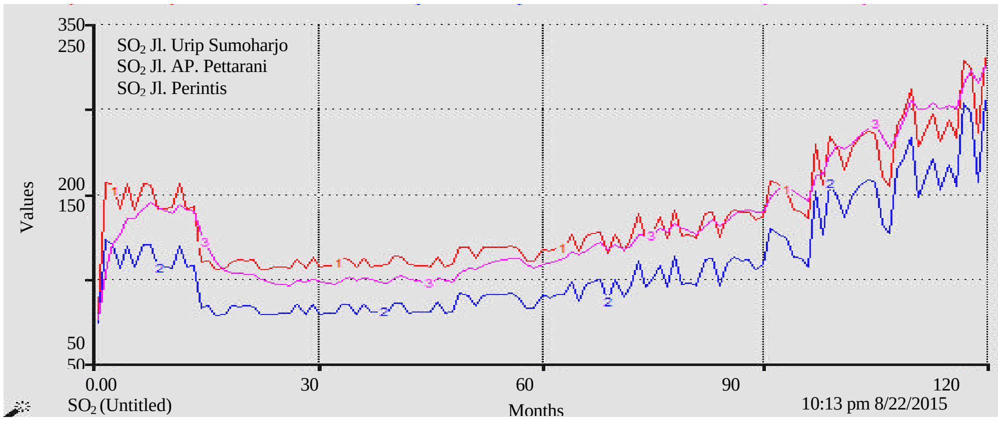

Fig. 3: Estimated SO_2 concentration in the next 10 years (2015-2025) At Jl. Urip Sumoharjo, Jl. AP. Pettarani and Jl. Perintis Kemerdekaan under the second scenario (2)

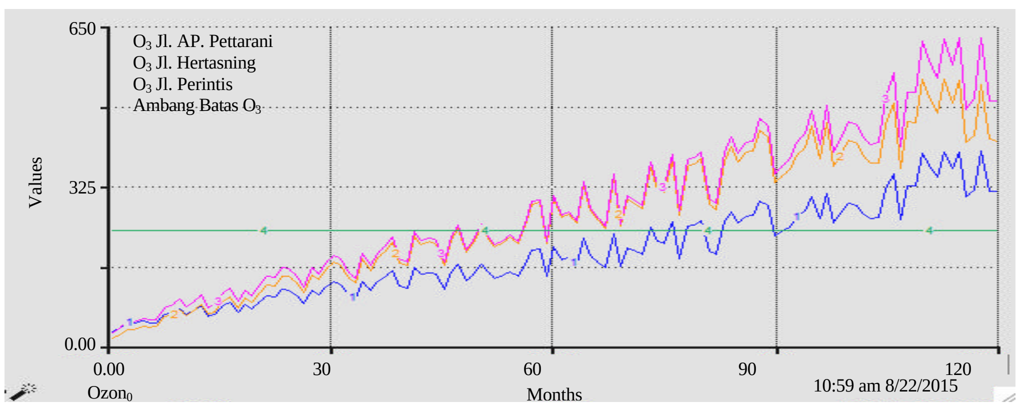

Fig. 4: Estimated O_3 concentration in the next 10 Years (2015-2025) At Jl. AP. Pettarani, Jl. Hertasning and Jl. Perintis Kemerdekaan under the second scenario (2)

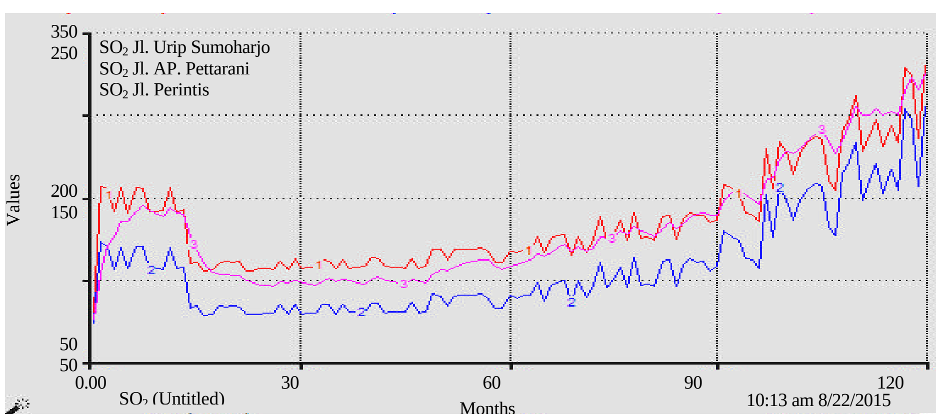

Fig. 5: SO_2 concentration estimation in the next 10 years (2015-2025) At Jl. Urip Sumoharjo, AP Pettarani and Jl. Perintis Kemerdekaan under the third scenario (3)

SO_2 experienced decrease concentration of 6286 mg/Nm^3 decreased to 4753 mg/Nm^3 in 2025, from an average of 0.03 times increased concentration becomes 0.02 times per month. Figure 6 shows the estimated experienced

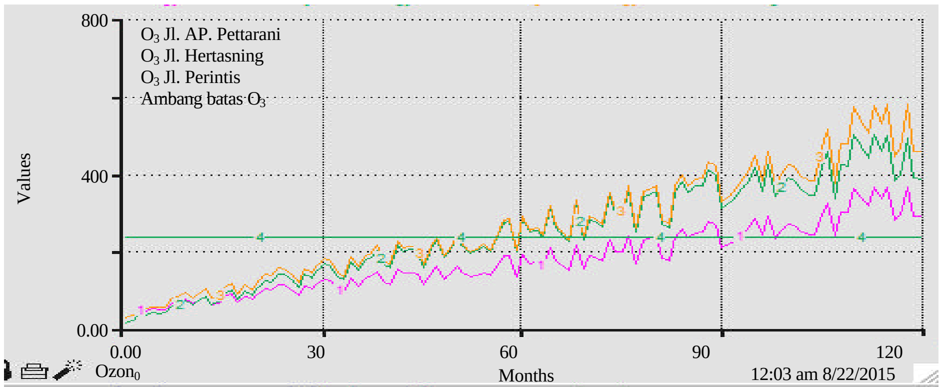

Fig. 6: Estimation of O_3 concentration in the next 10 years (2015-2025) at Jl. AP. Pettarani, Jl. Hertasning and Jl. Pioneer of independence under the third scenario (3)

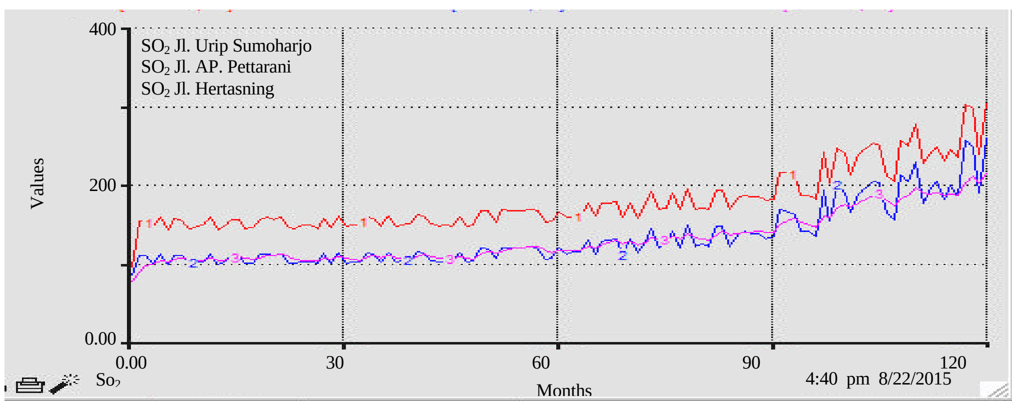

Fig. 7: SO_2 concentration estimation in the next 10 years (2015-2025) at Jl. Urip Sumoharjo, AP Pettarani and Jl. Hertasning based on the fourth scenario (4)

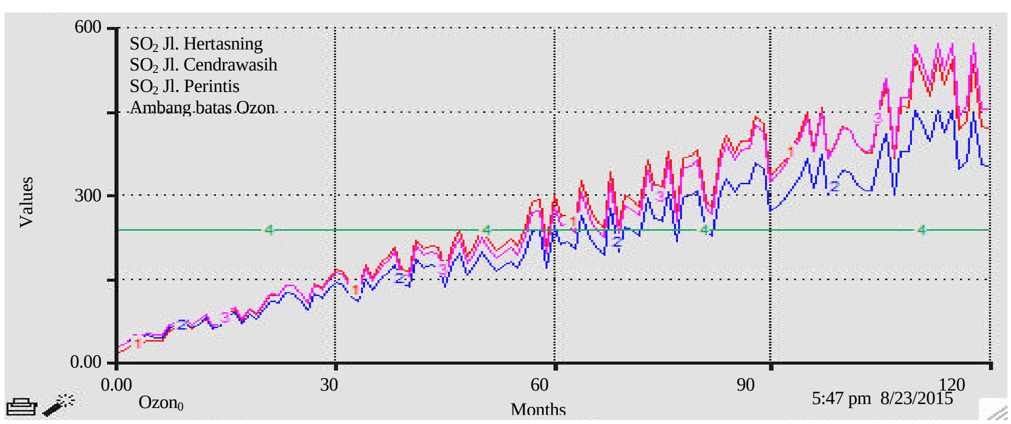

Fig. 8: Estimated O_3 concentration in the next 10 years (2015-2025) At Jl. Hertasning, Jl. Cendrawasih and Jl. Perintis Kemerdekaan under the fourth scenario (4)

decrease O_3 concentration of 4358-4000 mg/Nm^3 in 2025, the average monthly increase in the concentration of 0.15-0.13 times.

Scenario 4: Figure 7 and 8 show the results of the estimation of concentration of SO_2 and O_3 in the coming 10 years (2015-2025) in several main streets in Makassar

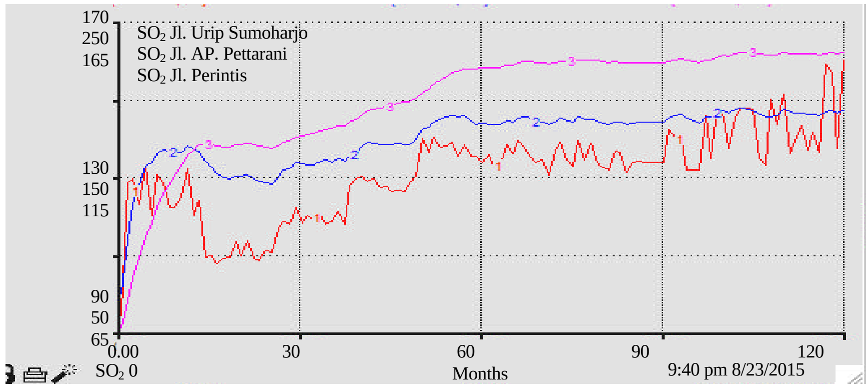

Fig. 9: SO_2 concentration estimation in the next 10 years (2015-2025) at Jl. Urip Sumoharjo, Jl. Hertasning and Jl. Hertasning based on combined scenario (2-4)

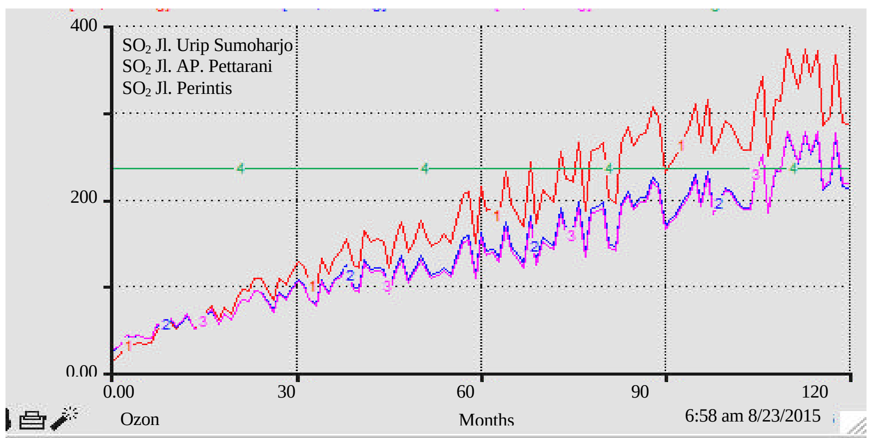

Fig. 10: Estimated O_3 concentration in the next 10 years (2015-2025) at Jl. Hertasning, Jl. Cendrawasih and Jl. Perintis Kemerdekaan under the fourth scenario (2-4)

with the regulatory scenario traffic services. Figure 7 shows the estimated SO_2 experienced decrease concentration of 6286 mg/Nm^3 decreased to 4306 mg/Nm^3 in 2025, the average increase in the concentration of 0.03-0.02 times per month. Figure 8 shows the estimated experienced decrease O_3 concentration of 4358 mg/Nm^3 be 3276 mg/Nm^3 in 2025, the average monthly increase in the concentration of 0.15-0.11 times.

Scenario 5: Figure 9 and 10 show the results of the estimation of concentration of SO_2 and O_3 in the 10 years to come (2015-2025) on the main roads of Makassar on the simulation scenario applying the combined scenario 3-4. Figure 9 shows the estimated SO_2 experienced decrease concentration of 6286 mg/Nm^3 decreased to 2675 mg/Nm^3 in 2025, from an average of 0.03 times increase in concentration to 0.01 times per month. Figure 10 shows the estimated experienced decrease O_3 concentration of 4358 mg/Nm^3 be 1815 mg/Nm^3 in 2025, the average monthly increase in the concentration of 0.15-0.06 times. This study aims to estimate the concentration of Sulfur dioxide (SO_2) and Ozone (O_3) in 10 years (2015-2025) which will come in several streets in the city of Makassar. Additionally, implemented several strategies to reduce the rate of increase in the concentration of SO_2 and O_3 in the model as a scenario and see the right strategy in suppressing the increase of the concentration. Several factors or variables that affect it is the type of vehicle, vehicle density, the volume of vehicles, fuel type, fuel consumption, vehicle emissions as well as meteorological factors at the study site. Modeling begins by outlining the components that will affect the effectiveness of the operating system which is studying the issue around which saw the problem as a whole. The main concept of dynamic system is an understanding of how all the objects in a system interact with one another. When it will run a model, it is necessary to specify the desired scenario and then perform simulations to include a policy or policy intervention factor (according to the scenario) that is built into the model. The policy change will affect other variables that will affect the overall performance of the system.

The first scenario 1 a scenario without any policy or regulatory intervention (do nothing) that is the real condition at this time, a condition where the air quality monitoring carried out by the relevant agencies but do not walk according to existing procedures. That there is a concentration value of SO_2 and O_3 concentration conditions at this time and are influenced by various factors, especially, from the transportation activities such as the number of vehicles. The number of vehicles is increasing, affecting the density of vehicles and increase exhaust emissions, resulting in the ambient air pollution.

The second scenario 2 is the scenario associated with regulatory restrictions on the age of the vehicle. The age limit of vehicles in this scenario that vehicles older than 10 years. This vehicle includes vehicle category reject or vehicles that can operate on a highway that is simulated in the model. In Indonesia alone, an age limit of vehicles in Surabaya applied specifically to public transit. Rules on vehicle age restrictions, especially, private vehicles in the city has also been there but the laws are not enforced. Basically, the type of pollutants released all types of motor vehicles is the same, only the composition was different due to the different conditions and the operating system between the vehicle's engine with each other. According to research conducted by Winarno (2014) that most vehicle engines generally have exhaust emissions to levels lower than the engines of older vehicles age, especially, flue gas CO, NO_2 and HC.

Third scenario 3 is the scenario associated with the use of fuel oil (BBM) that the transfer of premium consumption to pertamax. Fuel consumption will be growing as the number of vehicles increases. This is in line with research conducted by Katulistiyani and Nurhasanah (2015) that one that affects fuel consumption (including the type of gasoline, diesel and kerosene) in the city of Pontianak is a transport activities that have an impact on the increase in emissions of CO_2, SO_2 and NO_2. In addition, roads and vehicle speed also affect fuel consumption. Motor fuel is a complex product and contain various compounds that affect air quality. Research conducted by Punantoro (2013) that 88 kinds of premium fuels emit CO emissions by more than 6.27% CO emissions pertamax plus 95 at 5.82%. Diesel fuel used by automobiles is a type of diesel fuel that has the performance to the cetane number of 45. Basically, the fuel is intended for motor vehicles. SO_2 emissions issued vehicle diesel reached 45.53 mg/Nm^3 (Bachtiar, 2009).

The fourth scenario 4 relating to the regulation of traffic services. Increasing congestion on urban roads and roads outside the city caused the increase of vehicle ownership, increased economic activity, limited resources for the construction of highways and yet optimal operation of existing traffic facilities is a major problem in Indonesia.

The level of traffic service is a measure of the performance of roads, the maximum current that passes through a point on the freeway can be maintained unity hours in the prevailing conditions. The level of traffic services related to the number of vehicles on a road section. The more dense the vehicle, the lower the level of service roads, then the slower traveling vehicle. Slowing the speed of the vehicle increase the chances increase exhaust emissions and enhancing the concentration of pollutants in ambient air (Pamekas, 2013). Another study found that no significant associations were found between coarse particle levels and the number of hospital admissions for RD on warm days. In the two-pollutant models, PM2.5-10 levels remained significantly correlated with higher rate of RD admissions even controlling for sulfur dioxide, nitrogen dioxide, carbon monoxide or Ozone on cool days (Cheng *et al.* 2015), however, observed a borderline significant association between NO_2 exposure modeled as an averaged lag effect and ischemic stroke risk (Guo *et al*., 2017).

In the merger scenario 20 to 4, the estimated concentration of SO_2 and O_3 on the main roads of Makassar for 10 years (2015-2025) show an increase in concentrations lower than the simulated 2-4. Although, the increase is lower but the simulation results O_3 concentrations in some way still exceeds quality standards. It can be affected by several factors such as the amount of volume and density of vehicles that directly affects the amount of emissions released from vehicles and ultimately have an impact on ambient air quality in the area. Air quality monitoring should still be monitored because it can have an impact on the environment and public health. Some research suggests that throat irritation occurred at levels of SO_2, at 5 ppm or more. Individuals with symptoms of the disease are very sensitive to contact with SO_2, although with relatively low levels (Zakaria, 2013). The number of human activities, especially, the mobilization of transport have increased levels of ozone. From the simulation results 4 above, O_3 concentrations still exceed the quality standards in 2025. The health effects caused by O_3 is this gas to be lethal to cells of macrophage, stimulate thickening of the walls of the lungs, making breathing does not expand, it can not function in the exchange gas. In addition, the main psychological effects of brief exposure to O_3 is not able to breathe until total lung capacity.

CONCLUSION

Strategy, the most appropriate in reducing the rate of increase in the concentration of SO_2 and O_3 is the combined simulation (scenario 2-4) is an age restriction of vehicles over 10 years, the change of fuel from premium to pertamax and increased traffic services can reduce the rate of increase in the concentration of SO_2 by 2675 mg/Nm^3 with an increase of 0.1 times/month of initial conditions (Simulation 1) and at 1815 mg/Nm^3 with an increase of 0.06 times/month of initial conditions (Simulation 1) for O_3 concentration.

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