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Measuring Air Quality Over Denpasar City Indonesia in 2021

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Abstract
The imbalance number of rapid vehicles with transportation facilities has become the problem. In Denpasar, Indonesia, the congestion during peak hours happens so often. Based on the department of transportation in Denpasar, Indonesia, the number of vehicle ownership in Bali is 4.1 million in condition with a ratio of one resident to one vehicle with the current population of Bali Province approximately 4.2 million. Our study aim to measure the air chemical parameters of CO, O_3, SO_2, NO_2 and the physical parameters of the noise level. The research population is the atmosphere environment in the Denpasar City area. The research sample points were taken in the city center and the outskirts of Denpasar, with a total of 27 sample points. We employed impinge to get the airborne chemical gases and it is all analyzed with a spectrophotometer. We used a sound level meter to measure the ambient noise level. The data analysis was performed with free sample t test. The average ambient air chemistry obtained CO 517.34 µgr/Nm3, O3 0.17 µgr/Nm3, SO2 61.46 µgr/Nm^3 and NO_2 2.51 µgr/Nm3 and an average noise level 67.66 dBA. The number has found below the requirements Environmental Quality Standards and Environmental Damage Standard Criteria by Bali Governor. There is a difference in the mean parameters of CO, SO_2, NO_2 and ambient noise level in the downtown area. The average CO is 757.15 µgr/Nm^3, SO2 67.60 µgr/Nm^3, NO_2 3.77 µgr/Nm^3 and the noise level is 68.53 dBA with Denpasar outskirts mean CO 217.57 µgr/Nm^3, SO2 53.79 µgr/Nm^3, NO_2 0.95 µgr/Nm^3 and noise level 66.57 dBA. There is no difference in the average ambient O_3 in the city center area with an average of 0.22 µgr/Nm^3 with the outskirts of Denpasar an average of 0.11 µgr/Nm^3.

Keywords: CO, O_3, SO_2, NO_2, Noise

1. Introduction

Environment as a resource is an asset e needed to prosper the community (Supriadi, 2010; Wali et al., 2017). Government policy arrangements in creating environmental balance were actualized with the promulgation of the first regulations governing the environment, namely Law no. 4 of 1982 concerning Basic Provisions for Environmental Management, which was later replaced by Law no. 23 of 1997 concerning Environmental Management, which was subsequently replaced by Law no. 32 of 2009 concerning Environmental Protection and Management. Thus this law functions as a framework law to protect the environment and does not specifically regulate the prevention of air pollution (Sukanda, 2009).

According to (Hsia, et al. 2014) the air is the atmosphere that surrounds the earth whose function is essential to life. In the air, there is oxygen (O_2) to breathe, carbon dioxide (CO_2) for the process of photosynthesis by the chlorophyll of leaves, and ozone (O_3) to block ultraviolet from the sun. In big cities, the contribution of motor vehicle exhaust gases as a source of air pollution reaches 60-70%. Important factors that cause the dominant influence of the transportation sector on urban air pollution in Indonesia are rapid (exponential) growth in the number of vehicles; unbalanced transportation infrastructure with the number of existing vehicles; concentration-oriented urban traffic patterns, due to the centralization of economic activities and offices in the city center; derivative problems resulting from the implementation of existing urban development policies, such as residential areas moving away from the city center; equality of traffic flow time; type, age and characteristics of motorized vehicles; vehicle maintenance factor; type of fuel used; type of road surface; cycles and driving patterns (Nurdjanah, 2015).

A mixture of various gases and particles on the surface and surround the earth from the atmosphere. The composition of the air in the atmosphere that sustains human life consists of nitrogen (N_2) of 78.8% of dry air volume, oxygen (O_2) of 20.94%, argon (Ar) of 0.02%, and other gases as well as particles produced by human and natural activities (Nara et al., 2012). Regarding primary air pollutants, its composition will not change in the atmosphere both chemically and physically in a relatively long period of time (daily to yearly and will remain the same composition as the time emitted by the source). These pollutants include CO, CO_2, NO_2, N_2O, TSP, SO_2, methane, halogen compounds, metal particles and others. This pollutant has a long residence time in the atmosphere because it is stable to the physical chemical reactions of the atmosphere. According to (Nara et al., 2012; Sario et al., 2012), the concentration of pollutants in the air depends on weather conditions. Wind speed and direction, vertical temperature distribution, and humidity are the elements that play a role in this weather change(Balasubramanian, 2017). Wind speed affects the distribution of pollutants. Concentration of pollutant will be reduced if the wind is strong and distribute this pollutant horizontally or vertically. Land surface also affects wind speed, whether hilly or valley. Narrows are for wind can increase the speed of wind. Air that is polluted with particles and gases can cause health problems, especially in the physiological functions of organs such as the lungs and blood vessels or cause irritation to the eyes and skin(Ünver et al., 2019; Kim et al., 2018). Pollution due to particles and dust usually causes chronic respiratory diseases such as bronchitis chronic, pulmonary emphysema, asthma bronchial and lung cancer. Gaseous pollutants dissolved in the air can directly disturb the body to the lungs that absorbed by the blood vessel system(Hamanaka & Mutlu, 2018).

Motor vehicles and poor public transport systems contribute to the value of the exhaust gases produced. Sources of air pollution caused by human activities (anthropogenic) come from the burning of fossil fuels which generally contain carbon or hydrocarbon elements. Fossil fuels commonly used are octane which is a fuel with complex hydrocarbon compounds (Brimblecombe & Shooter, 1986).

Based on preliminary observations in Denpasar city during rush hour traffic jams, this is in accordance with data from the Bali Provincial Transportation Service that the number of vehicle ownership in Bali is 4.1 million. With a ratio of one resident to one vehicle, the current population of Bali Province is approximately 4.2 million. This study aims to measure air chemical parameters (CO, O_3, SO_2 and NO_2) and physical parameters, namely noise levels and analyze differences in air chemical parameters and noise levels between the outskirts and the center of Denpasar City.

2. Method

2.1 Research Design

This type of research is observational with Cross Sectional approach. The location of research was in Denpasar City. The research was carried out from March to October 2021. Regarding the population of research, it was the atmosphere environment in the Denpasar City area.

2.2 Sampling Procedure

Measurement of the chemical and physical quality of air is carried out in the Denpasar City area, which is divided into two areas. The first area with the sample point is in the city center and the second area the sample point is on the outskirts of Denpasar City. The location of sample points can be presented as shown in figure 1.

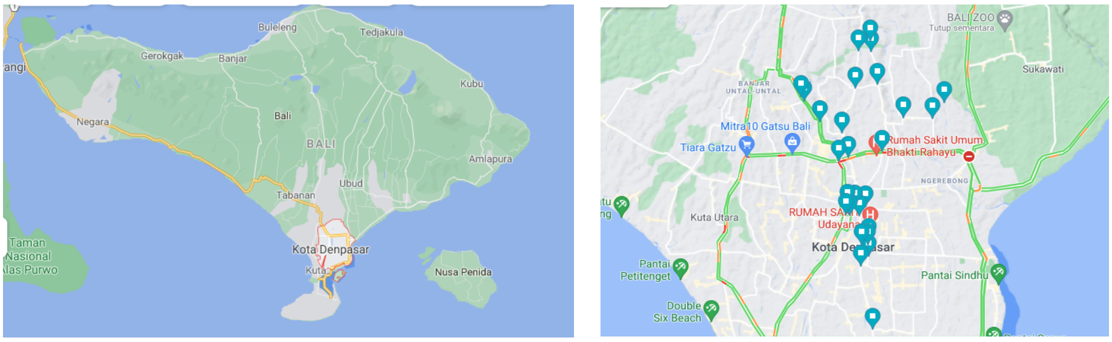

Figure 1: Location of sample points for measurement of chemical and physical air quality

The measurement locations for the downtown area were taken on Jalan Diponogoro, Jalan Sudirman, Jalan Hasanudin, Jalan Gajahmada, and Jalan Gatot Subroto where each path was taken 3 sample points. For the outskirts of Denpasar City, measurements were taken on Jalan Cokroaminoto, Jalan Ayani Utara, Jalan Antasura and Jalan Trenggana, each road taken 3 sample points, so the total number of samples was 27 samples.

Catching the levels of CO, O_3, SO_2 and NO_2 gases in the atmosphere was performed using air sampling with an impinger, by testing the O_3 parameter with the neutral buffer kalium iodide (NBKI) method using a spectrophotometer (7119-8:2017 SNI 2017), SO_2 parameter with the pararosaniline method using a spectrophotometer (7119-7:2017 SNI 2017) and the NO_2 parameter using Griess Zaltzman method with a spectrophotometer (7119-2:2017 SNI 2017). SNI stands for Standard Nasional Indonesia or Indonesia National Standardization. The measurement of carbon monoxide (CO) concentration in ambient air was performed by direct reading (real time sampling). This method uses a measuring instrument to directly determine the concentration carbon monoxide. This tool uses a sensor system based on the chemical and physical properties of the contaminants. The tool used in this research is CO Analyzer Kimo HQ 210, a carbon monoxide (CO) analyzer portable handheld used to detect and display CO gas concentrations between 0 and 2000 ppm. A sound level meter was used to measure the noise levels in ambient air. Differences in air quality in the outskirts and downtown Denpasar were analyzed using free sample t test at a 95% confidence level.

3. Results

3.1 Weather Description

The weather conditions at the time of sampling were quite sunny with the average air temperature during sampling 28.16 °C ± 1.36 °C, the air temperature during the study was at minimum 25 °C and maximum 30 °C. Air humidity during the study ranged from 70% to 97%, with an average humidity during the study 79.63% ± 7.50%. The wind speed during the research ranged from 11 km/hour to 19 km/hour with an average wind speed of 15.96 km/hour ± 1.93 km/hour.

Meteorology that has a big influence on changes in pollutant concentrations is wind speed. Pollution spread in an area is inseparable from the influence of strong wind speeds(Cichowicz et al., 2020). In addition to wind speed, mixing height also affects the dispersion of pollutants. The level of mixing height is affected by the inversion layer in which it will reduce the level of mixing height, therefore it limits the dispersion of pollutant in the atmosphere vertically. The higher the level of the inversion layer approaches the earth's surface, the smaller the area of mixing height. Thus, it results in a minimum pollutant dispersion process and poor ambient air quality (Salcido et al., 2020).

3.2 Air Chemical Parameters and Noise Levels

Measurement of air quality in Denpasar city area with air chemistry parameters CO, O_3, SO_2 and NO_2 obtained average results as shown in figure 2.

Figure 2: Average air chemical quality parameters CO, O_3, SO_2, NO_2 and noise levels in Denpasar City in 2021

Figure 2 shows that the air chemical quality parameters of CO, O_3, SO_2 and NO_2 in Denpasar city area are still far below the requirements of the Bali Government Regulation number 16 of 2016 concerning Environmental Quality Standards and Environmental Damage Standard Criteria. The noise level in the Denpasar city area exceeds the maximum noise level for residential area activities of 55 dBA. For the downtown and outskirts areas of Denpasar, the results of air chemistry parameters and noise levels can be seen in Table 1.

Table 1: Air chemical quality parameters (CO, O3, SO2 and NO2) and noise levels in the downtown and outskirts of Denpasar in 2021

Location	Coordinate of Sample	CO µgr/Nm^3	O3 µgr/Nm^3	SO2 µgr/Nm^3	NO2 µgr/Nm^3	Noise Level
Downtown of Denpasar						
Jalan Diponogoro,	-8.669586, 115.215508	624.65	0.12	60.37	2.02	65.80
	-8.700396, 115.219393	591.78	0.67	71.31	4.05	74.30
	-8.677388, 115.215233	629.03	0.46	58.48	1.97	72.20
Jalan Sudirman,	-8.667628, 115.218006	857.70	0.13	66.97	6.70	66.40
	-8.669612, 115.217922	778.73	0.07	73.76	3.05	68.80
	-8.673754, 115.218045	680.02	0.46	60.37	4.02	66.70
Jalan Hasannudin,	-8.659124, 115.214823	710.73	0.48	77.54	3.08	69.20
	-8.658600, 115.211279	684.41	0.14	83.95	3.05	72.40
	-8.658483, 115.209874	680.02	0.09	66.03	8.18	65.30

Jalan Gajah Mada,	-8.655099, 115.210614	916.16	0.07	66.10	0.34	66.70
	-8.655478, 115.213040	679.45	0.10	62.25	2.08	65.20
	-8.655721, 115.216906	696.98	0.10	65.65	6.70	68.30
Jalan Gatotsubroto	-8.639111, 115.207539	1184.55	0.10	63.90	0.93	70.20
	-8.635348, 115.222969	936.67	0.16	73.76	5.20	67.30
	-8.637759, 115.210760	706.34	0.15	63.49	5.11	69.10
Average		757.15	0.22	67.60	3.77	68,53
Outskirts of Denpasar						
Jalan Cokroaminoto	-8.624477, 115.200819	297.75	0.15	58.63	1.65	66.40
	-8.616998, 115.195011	285.80	0.08	59.97	0.85	67.30
	-8.615357, 115.193843	210.12	0.07	48.47	0.31	64.90
Jalan A Yani Utara,	-8.612301, 115.213214	116.51	0.14	65.14	2.24	67.80
	-8.628682, 115.208676	112.53	0.20	59.20	0.62	68.20
	-8.598862, 115.214529	174.27	0.09	48.47	1.23	64.80
Jalan Antasura,	-8.611111, 115.221281	355.01	0.15	65.34	0.59	68.30
	-8.599041, 115.218905	223.06	0.14	66.10	0.93	67.20
	-8.595131, 115.218767	317.67	0.11	42.15	0.31	65.60
Jalan Trenggana	-8.623135, 115.230410	284.14	0.11	25.29	1.09	65.20
	-8.623485, 115.240942	119.50	0.09	65.14	0.93	66.70
	-8.617563, 115.245095	114.52	0.06	41.58	0.62	66.40
Average		217.57	0.11	53.79	0.95	66.57

According to Table 1, the chemical parameters of air CO, O_3, SO_2, NO_2 and the noise level for outskirts areas are smaller than the area of downtown. This shows that the level of vehicle density and congestion in the outskirts of Denpasar is lower than the center of Denpasar City.

3.3 Differences in Chemical and Physical Air Quality

Table 2 is the results of independent t-test and Mann Whitney for air chemical parameters (CO, O_3, SO_2, NO_2) and noise levels.

Table 2: Independent t test results and Mann Whitney for air chemical parameters (CO , O_3, SO_2, NO_2) and noise level

Variables	Mean Downtown μgr/Nm^3	Mean Outskirts μgr/Nm^3	Sign independent t test / Mann Whitney
CO	757,15	217.57	0.000
O3	0.22	0.11	0.260
SO2	67.60	53.79	0.004
NO2	3.77	0.95	0.000
Noise	68.53 dB	66.57 dB	0.023

Based on Table 2, it shows the significance value of air chemical parameters (CO, SO_2, NO_2) and the noise level is less than 0.05, which means that there is a difference in the results of the average measurement of air chemical parameters (CO, O_3, SO_2, NO_2) and the noise level between the downtown and outskirts areas of Denpasar. Meanwhile, for parameter O_3, a significance value of 0.260 is greater than 0.05, indicating that there is no difference in the average O_3 parameter between the downtown and outskirts areas of Denpasar.

4. Discussion

Exposure to high concentrations of CO can have significant effects harmful to the human body. Harmful effects on human health have been observed with CO exposure at concentrations of 12,000 to 17,000 μg/Nm^3. This health effect consists of physiological stress, especially in patients with heart disease, blood poisoning, and so on (Manisalidis et al., 2020; Munfarida, 2015). According to (Rozante et al., 2017) stated that high concentrations of carbon monoxide are considered very toxic to humans because they can cause acute poisoning, and death due to suffocation. The interaction of hemoglobin with CO is 240 times greater than with oxygen (O_2). So, carboxyhemoglobin will be formed which that should be formed oxyhemoglobin. When the atmosphere is overwhelmed with CO, O_2, human will suffer suffocation and causing death (Rose et al., 2017).

Carbon monoxide (CO) is produced by chemical reactions in the atmosphere between hydroxyl radicals (OH) and methane (CH_4) and other hydrocarbons, in addition to reactions between alkenes and ozone (O_3), and reactions of isoprene and terpenes with OH and O_3 (Rozante et al., 2017). In addition, other meteorological factors besides air temperature can also affect the concentration of CO in the atmosphere. These meteorological factors include air pressure, and the structure of the boundary layer. Air pressure will affect the diffusion of CO gas in the horizontal and vertical directions in the air, and the boundary layer structure plays an important role in the diffusion of CO gas in the vertical direction (Zeng & Zhang, 2017).

Ozone at a concentration of 0.3 ppm can cause irritation to the nose and throat (J. J. Zhang et al., 2019). Contact with ozone at concentrations of 1.0 – 3.0 ppm for 2 hours causes severe dizziness and loss of coordination in some sensitive persons. While contact with a concentration of 9.0 ppm for some time can cause pulmonary edema in most people. The combination of ozone with SO_2 is very dangerous as it causes a decrease in the ventilation function when exposed to large amounts. Impaired ventilation function may return to nearly normal lung function in people exposed to low levels. Photochemical oxidants are atmospheric components produced by the photochemical process, a chemical process that requires light, which will oxidize components that cannot be oxidized immediately by oxygen gas. The compounds formed are secondary pollutants produced due to the interaction between primary pollutants and sunlight. Hydrocarbons are components that play a role in the production of photochemical oxidants. This reaction also involves the NO_2 photolytic cycle. The most dangerous secondary pollutants produced by the hydrocarbon reactions in the cycle are ozone (O_3) and peroxyacetylnitrate, which is one of the simplest components of the peroxyacylnitrate (PAN) group. The main oxidants are ozone (O_3), nitrogen dioxide (NO_2) and peroxyacylnitrate (PAN). NO_2 comes from the photochemical reaction of NO with oxygen in the air. Meanwhile, ozone and PAN come from photochemical reactions of NO, NO_2, SO_2 and hydrocarbon radicals.

Ozone is not a hydrocarbon but O_3 concentrations in the atmosphere rise as a direct result of the reaction of hydrocarbons, while PAN is derived hydrocarbons. The product of the reaction between O and hydrocarbons is a highly reactive intermediate product called free radical hydrocarbon (RO_2). Such free radicals can further react with various components including NO, NO_2, O_2, O_3, and other hydrocarbons (Petersen, 2017).

Sulfur dioxide gas is formed when the golden yellow powdered sulfur present in coal and fuel burns. Other sources of sulfur dioxide gas besides motor vehicle fumes are from heating in households and burning waste/wood charcoal. After hours or days mixed in the air, this sulfur dioxide forms very fine particles called sulfates and can penetrate the deepest parts of the lungs and mix with water in the lungs to form sulfuric acid, but when in the air this sulfate will react with water in the atmosphere and will cause acid rain. In addition to its effects on humans, sulfur dioxide also affects plants and animals. The effect of SO_2 on animals is almost similar to the effect of SO_2 on humans. In plants, sulfur dioxide affects the discoloration of the leaves from green to yellow or the occurrence of white spots on the leaves of plants.

The presence of nitrogen dioxide gas in the air is not only caused by motor vehicle/transportation fumes (39.3%) but also from the burning of waste, wood charcoal and natural gas combustion. The concentration of NO_2 in the air in a place varies throughout the day depending on the sunlight and the mobility of vehicles as well as the activities of the inhabitants(K. Zhang & Batterman, 2014). From the calculation of the velocity of NO_2 emission, it is known that the average residence time of NO_2 in the atmosphere is approximately 3 days, while the retain time of NO is 4 days, and this gas is accumulated in the air which when mixed with water causes acid rain.

Traffic noise arises from the sound produced by motorized vehicles, especially from vehicle engines, exhausts, and the interaction between the wheels and the road. Heavy vehicles (trucks, buses) and passenger cars are the main noise sources on the highway. In general, control strategies Noise is divided into three elements, namely control of noise sources, control of noise paths and control of noise receivers (Djalante, 2010). Impact noise can have an effect; 1) physical effects: damage that occurs to the hearing apparatus (auditory effect), 2) psychological effects: damage to parts of body functions such as increased blood pressure, insomnia, digestion becomes nauseous and restless, 3) emotional effects: changes in emotional as an expression of noise in the form of annoyance or feeling disturbed, it can even cause mental disabilities, and 4) operational effects: noise can reduce work power both physically and mentally in the form of communication disorders and decreased sharpness of mind (Sugiarta, 2008; Anees et al., 2014).

According to table 2, the results of the measurement of air chemistry parameters are still below the requirements of the Bali Governor Regulation number 16 of 2016 concerning Environmental Quality Standards and Environmental Damage Standard Criteria for 1 hour measurement, the maximum level requirement for CO parameters is 30,000 µgr/Nm^3, O_3 is 235 µgr/Nm^3, SO2 of 900 µgr/Nm^3, NO2 of 400 µgr/Nm^3. The results of this study were obtained during the Covid-19 pandemic with government policies in the form of implementing restrictions on community activities (PPKM) so that population mobility by using vehicles was limited to access Denpasar city. The results of this study illustrate that the level of density or congestion between the outskirts and the downtown area is also different. There are differences in the values of air chemistry parameters CO, O_3, SO_2, NO_2 and noise levels in each location due to the contribution of busy motorized vehicles during peak hours and office activities.

Conclusion

Our work has led us to conclude that gas concentrations in Denpasar city regarding air chemistry such as CO, is in average of 517.34 µgr/Nm^3, O_3 with average 0.17 µgr/Nm^3, SO_2 with average 61.46 µgr/Nm^3 and NO_2 average 2.51 µgr/Nm^3 . These concentrations are still below the requirements of Bali Governor regulation number 16 of 2016 concerning Environmental Quality Standards and Environmental Damage Standard Criteria. The average noise level in the Denpasar City area is 67.66 dBA, exceeding the maximum noise level for residential area activities of 55 dBA. There is a difference in the average concentration of CO gas in the city center area with an average of 757.15 µgr/Nm^3 with an average of 217.57 µgr/Nm^3 in outskirts of Denpasar on the significance level of 0.000. There is a difference in the average concentration of SO_2 gas in downtown area with an average of 67.60 µgr/Nm^3 compared to the outskirts of Denpasar with an average of 53.79 µgr/Nm^3at a significance of 0.004. Besides, there is a difference in the average concentration of ambient NO_2 gas in the downtown area with an average of 3.77 µgr/Nm^3 compared to the outskirts area with an average of 0.95 µgr/Nm^3 at a significance of 0.000. However, there is no difference in the average of O_3 gas in the downtown in amount of 0.22 µgr/$Nm^3$with the outskirts of Denpasar at average of 0.11 µgr/Nm^3 at a significance of 0.260. At last, there is a difference in the average noise level in downtown area with an average of 68.53 dBA as opposed to outskirts area with an average of 66.57 dBA on the significance of 0.023.

The evidence from this study suggests to the related agency to monitor air quality regularly, regulate traffic flow, build pedestrians lane, arrangements for different working hours, educate groups and schools to participate in carrying out a vehicle-free day, conducting strict smoke testing on all public and private vehicles as well as limiting the age of vehicles that are operationally not roadworthy and carrying out mass reforestation.

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