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The Investigation of Carbon Monoxide Concentration at Selected Areas in the Federal Territory of Kuala Lumpur, Malaysia

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ABSTRACT

This study aims to study carbon monoxide (CO) concentration in the Federal Territory of Kuala Lumpur (FTKL), which involves primary data through field studies with a quantitative approach. The CO sampling method involves 12 observation stations covering six main zones for eight days. Data are collected twice a day at night and day between 01:00 - 04:00 AM and 1:00 - 4:00 PM. The duration of the sampling is 30 minutes for one sample. Sampling time may vary for stations but still within the stipulated time. The instrument to measure CO is the Model Carbon Monoxide meter AS700A. The Analysis is descriptive. The findings show that the lowest value at night is stations 3 and 10, with an average concentration value of 5 parts per million (ppm). Simultaneously, the highest CO value in the afternoon is at station 1 and station 4, with a concentration of 12 ppm. The overall average at each station is high, between 7 to 12 ppm. Most stations show readings exceeding the WHO's standard (5 ppm/hour). However, CO's concentration is considerably under control because it does not exceed the standard limits of NAAQS and DOE. Overall, CO concentrations are higher in the day than in the morning and on weekdays than on weekends. In conclusion, vehicle increase significantly contributes to increased CO concentrations in Kuala Lumpur. The proactive and effective measures to reduce the well-being of life to maintain human health and the environment.

Keywords: Concentration; carbon monoxide; Kuala Lumpur; pollution; atmospheric.

INTRODUCTION

Most of the world's cities have problems related to CO. This problem is because some of the world's population lives in urban areas. At the same time, they use fossil-powered vehicles. Urban CO emissions are always from hydrocarbon methane and non-methane oxidation. Non-native sources are often fossil fuel combustion from vehicles (Clearbaux et al., 2008; Rozante et al., 2017). CO concentration resulted low with the help of the oxidation method using hydroxyl radical (OH). Some of the elements in CO will go to the water resulting in higher rainwater acidity. CO will last anywhere from a few weeks to a few months in the atmosphere (Clearbaux et al., 2008). The transportation sector emitted significantly more CO as the city grew. Combustion is the heat released from a fuel and an oxidant reaction. Typically, the fuel is carbon-rich, such as gasoline or wood, and the oxidant is air, though there are other oxidizing agents, such as hydrogen. However, without air as an oxidant, combustions do occur rarely. The heat generated by combustion is commonly used for cooking, heating, or produced for electrical power generation. Carbon monoxide (CO) is the main product of hydrocarbon fuel combustion. However, impurities in the fuel or nitrogen present during combustion can lead to emissions in the air in addition to incomplete combustion. Many cancer-causing pollutants originate inside the internal combustion engine (diesel, gasoline, and jet engines) (Straif et al., 2013).

The ocean, land, and living organisms are part of a chemically complex and dynamic system that interacts significantly with the atmosphere. A necessary process in the biosphere is converting relatively complex substances into simpler ones in the atmosphere. The compounds in this group include hydrocarbons (RH), carbon monoxide (CO), and ammonia (NH). Other elements also come from hydrogen and carbon-carbon systems, including fluorocarbons and hydrochlorofluorocarbons. Oxidation reactions are also known as nature's atmospheric "cleansing" process. Without these gas cleaning procedures, the levels of many substances in the air and the biosphere could rise to such an excessive concentration that they would alter the atmosphere's chemical nature and global warming. Oxidation became a significant atmospheric reaction on earth once molecular oxygen (O_2) from photosynthesis had reached sufficiently high levels. This oxygen could then photo-dissociate in the atmosphere to make ozone (O^3). When O^3 absorbs UV light with a wavelength less than 310 nm, it produces excited oxygen atoms (O(1D)) that attack water vapor and produce the hydroxyl free radical (OH) (Prinn, 2003). Above all, the hydroxyl radical determines the oxidative capacity of the O^2- and H_2O-rich atmosphere (Levy, 1971; Chameides & Walker, 1973; Ehhalt, 1999; Lelieveld et al., 1999; Prather et al., 2001). Its global average concentration in the troposphere in the early 2000s was only 106 radical cm 23 or 6 parts in 1014 by mole (Prinn et al., 2001). However, its impact is immense, and its life cycle is complicated. It interacts with CO to produce CO2 in a matter of seconds (and also a hydrogen atom, which combines with O2 to form hydroperoxyl free radicals, HO2).

The rapid development of Malaysia since its independence in 1957 has led Malaysia to become a prosperous developing country known to the world. Transportation is one of the main pillars of development, especially in economic and infrastructure development. The country's rapid development has made Malaysians a vibrant society, where daily movement is swift and sometimes causes stress, especially for city residents facing stranded and congested vehicles (Nafhatun, 2016). However, despite these developments, it has led to the release of pollutants such as carbon monoxide, especially in the urban centers that are the study location of choice. The issue of pollutant gas pollution is one of the critical issues and is often associated with Malaysia's development and progress. The significant increase in motor vehicles and the rapid development of the industrial sector has increased air pollutants in the environment (Kho, Law, Ibrahim & Sentian, 2007). Therefore, the increase in pollutant gas in Kuala Lumpur has had many effects on humans. Also, the increase in CO is very harmful to people around the city. The air quality in FTKL is still at a low level compared to the cities of developed countries. However, CO's increase can be affected by a comparison of 1.8 above Tokyo (Mohd Talib et al., 2006). Nearly 82 percent of the more than three million tons of air pollutants by motor vehicles (DOE, 2013; DOE, 1996). Air pollutants such as CO are released from the exhaust and hydrocarbons through the carburetor and evaporation in the oil tank. Also, engine technology, vehicle age, and fuel influence the number of pollutants released (Cernuschi et al., 1994).

Carbon monoxide is a colorless, odorless gas. Although this gas is generally not harmful to life, it can cause human death in just a few minutes of exposure, only for concentrations exceeding 5000 ppm. Carbon monoxide reacts with hemoglobin in the blood to form carboxyhemoglobin (COHb). In addition to death, human exposure to carbon monoxide results in impaired vision, disrupting the body's balance, and disrupting the vascular system. According to Yusri, Mardiana, and Norli (2014), carbon monoxide is a colorless gas and tastes. It is a product resulting from incomplete combustion, such as vehicle exhaust, and contains carbon. According to Werk, Warner, and Davis (1998), CO gas is stable and has a shelf life of 2 to 4 chunks in the atmosphere; it is also an element of the troposphere. Carbon monoxide comes from natural and anthropogenic processes, forming an intermediate material for chemical reactions between carbon fuels and oxygen. The concentration of CO in the air is ppm or parts per million. A gas analyzer with a percentage of volume is used to measure the CO level, of which one ppm equals 10-4%. Usually, CO comes from imperfect combustion in vehicles and small amounts (less than 0.5%).

The effects of CO are so diverse that CO is one of the criteria for carbon monoxide air pollutants and is essential as a benchmark for air quality inside and outside buildings because it has a detrimental effect on human health (Yusri et al., 2014). EPA (2010) explains that carbon monoxide affects human health by reducing oxygen levels to use organs and tissues in the human body, leading to chest pain, heart pain, and other symptoms that can cause health problems. Healthy individuals can receive low levels of carbon monoxide exposure, but for individuals with poor immunity, high or low concentrations enrich the individual's health (Ideriah, 2008). Carbon monoxide at high concentrations results in shortness of breath. (Yusri et al., 2014). When humans breathe, carbon monoxide enters the body through the upper respiratory system, down to the lungs, and directly to the bloodstream through the alveoli. Carbon monoxide also interferes with the blood's ability to deliver oxygen to the human body. Hemoglobin is a protein in the blood cells that are usually attached to oxygen (to form hemoglobin) and delivered to the rest of the body (IAPA, 2003).

Most of the CO comes from motor vehicle sources. A vehicle is a structure capable of moving or being moved or used to transport people or make constant contact with the earth's surface while moving. A motor vehicle is fitted with a petrol or diesel engine (Environmental Quality Act, 1974; Zenneti, 1990). Air pollution from motor vehicles is divided into exhaust gas, evaporation, and refueling. Gas emissions from vehicle exhaust depend on the type of fuel used and the fuel's combustion temperature. The highest pollutant gas produced by vehicle exhaust is nitrogen oxide. The engine's complete combustion produces carbon monoxide and water, while incomplete combustion produces oxygen, carbon monoxide, and hydrocarbons. Natural gas, aviation gasoline (Avgas), motor oil (Mogas), and aviation turbine fuel are among the fossil fuels used in Malaysia's transportation sector (ATF or Avtur) (Anwar et al., 2010). Most vehicles in Malaysia run on research octane number 97 (RON97) or RON95 gasoline. RON98 gasoline will only be available in a few locations. Because of the lower price in Malaysia, people intend to use RON95. Most motorcycles, on the other hand, prefer to use RON95. However, heavy vehicles, such as trucks and buses, frequently use diesel. Malaysia has a tight grip on the processing of poisonous chemicals like CO. The Environmental Quality Act of 2014 allows CO production to exceed 1000 g/m^3. As a result, all vehicle manufacturers must ensure that the CO production level for the vehicles they use does not surpass the requirement for obtaining a Malaysian vehicle sales license.

On the other hand, commercial vehicle owners or persons must ensure that their vehicles emit fewer CO emissions, and if found to be above the standard, they can be sued (AGC, 2014). In comparison to the United States (2.61 g/km or 2610 g/m) and the European Union (1.0/0.5 g/km or 1000/500 g/m), the European Union (1.0/0.5 g/km or 1000/500 g/m) (Directorate-General for Internal Policies Department A: Economic and Scientific Policy, 2016). Malaysia does not have specific laws on CO pollutants production other than the standards used in the United States or the European Union.

This article will discuss CO concentrations obtained from the six FTKL zones. Two observation stations for every zone and located in the development area of Kuala Lumpur. CO-level research in Kuala Lumpur is vital to assess the need for land development planning. This research emphasizes the community's well-being by minimizing the CO production level in Kuala Lumpur. Well-being planning also involves developing a transport network to establish more efficient public transport and reduce the number of vehicles on the road. It, in turn, reduces the use of oil such as diesel or petrol used during vehicle operation.

MATERIAL AND METHODS

Study area

Kuala Lumpur is the most considerable capital and city in Malaysia. It is known as the Federal Territory of Kuala Lumpur, apart from the Federal Territory of Putrajaya and the Federal Territory of Labuan, administered directly by the Federal Government of Malaysia in Malaysia has a state administrative system. The land area of Kuala Lumpur is 244 km^2 (Junaidi et al., 2017, Nasir et al., 2020a; Nasir et al., 2020b) and is a metropolitan area known as the Klang Valley. The Klang Valley is also part of the Selangor State area due to the overflow of development coming out of Kuala Lumpur towards its neighboring state, Selangor. According to the Kuala Lumpur Structure Plan 2020, Kuala Lumpur City has six strategic zones bordered by a network of major roads, railways, and river corridors. The zones are the City Center, Wangsa Maju-Maluri, Sentul-Manjalara, Damansara-Penchala, Bukit Jalil-Seputih, and Bandar

Tun Razak-Sungai Besi (DBKL, 2020). There are two stations designated for data observation in each of these zones. Thus there are 12 stations involved (Figure 1). Table 2 shows the date, day, and whether it is a working day. Out of 8 days of data observations, five days were on weekdays, and three days were on weekends. Only 12 stations represent all places in Kuala Lumpur. Since FTKL has six zones, two stations to represent 1 zone are considered sufficient.

Breathing CO at high concentrations leads to reduced oxygen transport by hemoglobin, which has health effects that include impaired reaction timing, headaches, light-headedness, nausea, vomiting, weakness, clouding of consciousness, coma, and, at high enough concentrations and long enough exposure, death (National Research Council, 2002). CO will continue to be in the air until agents such as rainwater decompose into rainwater, are brought down to the earth's

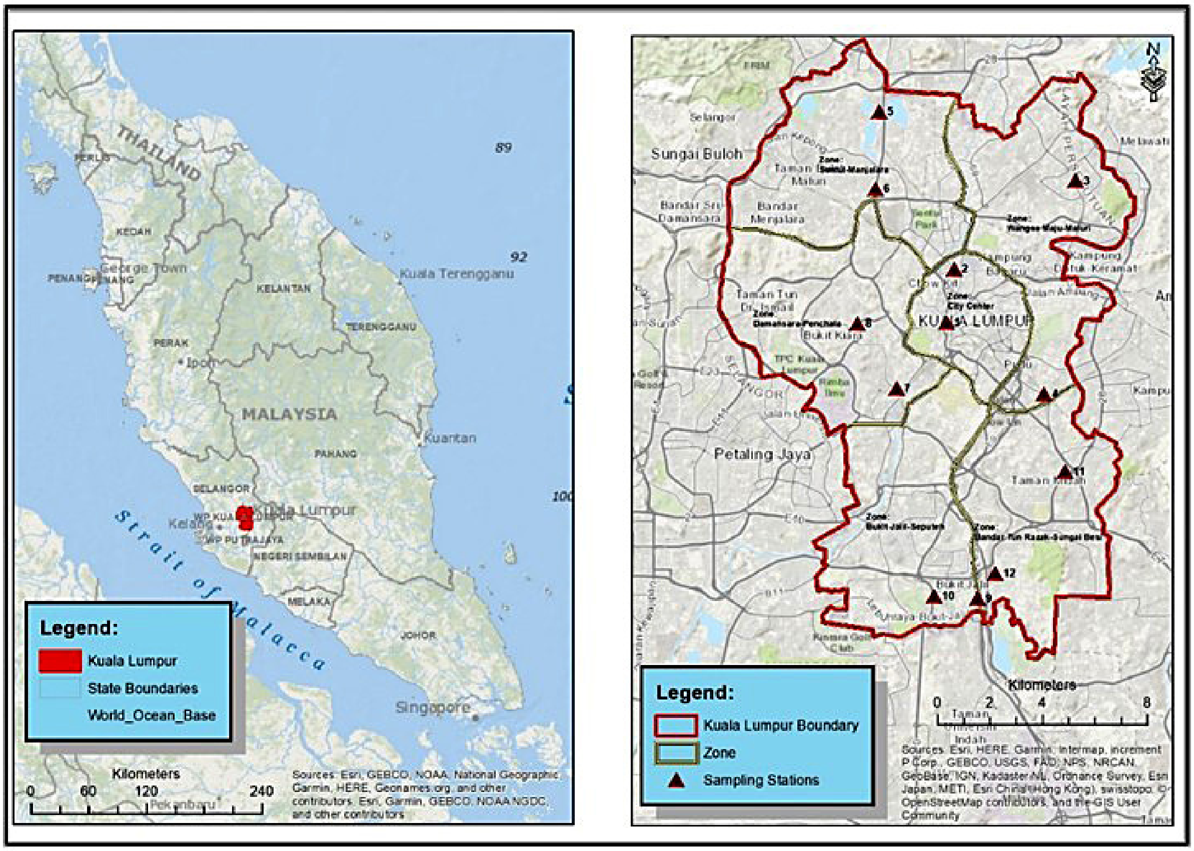

Figure 1. Study area and sampling location

Table 1. Zone, area, and sampling station locations

Station	Zone	Locality area	Longitude (X)	Latitude(Y)
1	A (City Center)	Dataran Merdeka	101.693409	3.14998
2	A (City Center)	Asia Park	101.696091	3.168166
3	B (Wangsa Maju-Maluri)	Sri Rampai	101.737697	3.198496
4	B (Wangsa Maju-Maluri)	Sunway Velocity	101.726811	3.125396
5	C (Sentul-Manjalara)	Sri Utara	101.67042	3.222147
6	C (Sentul-Manjalara)	Kepayang Road	101.669224	3.195686
7	D (Damansara-Penchala)	Petron Bangsar	101.676356	3.127313
8	D (Damansara-Penchala)	Damansara City Center	101.662936	3.149613
9	E (Bukit Jalil-Seputeh)	Standard Chartered	101.704135	3.055385
10	E (Bukit Jalil-Seputeh)	Stadium Bukit Jalil	101.689191	3.056201
11	F (Tun Razak Town-Sungai Besi)	Tesco Extra Cheras	101.734154	3.098915
12	F Tun Razak Town-Sungai Besi)	Sungai Besi Town	101.710104	3.064034

Table 2. Sampling days

Day	1	2	3	4	5	6	7	8
Date	11/8/2019	12/8/2019	13/8/2019	14//8/2019	15//8/2019	16//8/2019	17//8/2019	18//8/2019
Day	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Working day	Weekend	Working day	Working day	Working day	Working day	Working day	Weekend	Weekend

surface, and back into nature through the carbon and oxygen cycles. If there is a lack of agents, such as rain, then CO concentration will continue to increase in the air daily. This research was conducted at the time of the lack of rainwater to investigate the amount of CO accumulated on weekdays, with many private vehicles and holiday time as differences.

Data collection

The data used are primary and secondary. The primary data is through field study methods and observations at the study station location. The sampling location selection is based on several criteria, such as within the six designated zones. The location is also not sheltered from any physical or building features. The chosen location is a non-covered parking area to avoid elements such as CO trapped in one area. The location of the station is as in Table 1. Every day, CO has sampling twice, day and night. Day sampling is between 1 to 4 PM to get the optimal value because, at that time, the high number of vehicles in the city produce CO. Night sampling is between 1 to 4 AM with the same location. The sampling time may vary from each station due to the constraint of moving from one station to another. The observation using a carbon detector with the time of each observation at the station is 30 minutes. Observation and photographic methods are essential to provide an overview as evidence that can increase the study results' validity and reliability. The instrument used is a single gas-detector branded BW. Clip Real-time. BW. Clip Real Time continuously displays the concentration of a specific gas in the ambient environment. The supplier company has tested and calibrated before tool delivery.

Data analysis

The Analysis used is descriptive. The descriptive Analysis used was to obtain the tendency to centralize the concentration of CO obtained from the observations. Apart from the average for each observation station, the average observation time and the overall average are required to identify CO concentration patterns at selected places in Kuala Lumpur City. Apart from that, other analyses involved include percentage and standard deviation.

RESULTS AND DISCUSSIONS

CO concentration at night-time

Table 3 shows the CO concentration value obtained from night observations between 1 to 5 AM, with minimal traffic. On average, the CO level is at 6.5-6.3 ppm. This situation is good, which shows that CO pollution in the Kuala Lumpur area is low. The value obtained is also less than the standard set by DOE, which is 30 ppm (8-hour observation) or nine ppm (1-hour observation). Even far below the standards set by USEPA (50 ppm) and NAAQS (35 ppm). However, this value still exceeds the standard by WHO (5 ppm). Generally, health risks such as suffocation from CO gas in the air are still low.

The CO concentration distribution for all stations shows the highest value in the night is at station two, which is Asia Park, with a CO concentration value of 10 ppm, while the lowest CO distribution is at station three and station ten, which is the Sri Rampai area and Bukit Jalil Stadium with recorded a CO value of 5 ppm. The value of CO concentration in the downtown zone at station 2 (Asia Park) is high due to the increase in the number of vehicles in the area, especially the downtown area. Also, the activities carried out by the surrounding residents contribute to the increase in CO in the area. The release of carbon monoxide from vehicles is a factor in why the value of CO concentration is relatively high in the area. The area's CO concentration value is low at night for station 3 (Sri Rampai) and station 10 (Bukit Jalil Stadium). The low CO concentration at that time was due to the low number of vehicles in the area. Besides, this area is also a few meters from the main road, where the CO distribution is low.

Table 3. CO concentration at night

Station	Day (ppm)							
	1	2	3	4	5	6	7	8
1	8.00	8.00	8.00	8.00	9.00	8.00	8.00	8.00
2	10.00	8.00	8.00	8.00	7.00	8.00	8.00	8.00
3	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
4	9.00	9.00	9.00	9.00	8.00	9.00	9.00	9.00
5	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
6	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
7	6.00	6.00	7.00	6.00	6.00	6.00	6.00	6.00
8	5.00	5.00	6.00	5.00	5.00	5.00	5.00	5.00
9	6.00	6.00	6.00	7.00	6.00	7.00	6.00	6.00
10	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
11	6.00	6.00	6.00	6.00	5.00	6.00	6.00	6.00
12	5.00	6.00	6.00	6.00	5.00	6.00	5.00	5.00
Average	6.50	6.42	6.58	6.50	6.17	6.50	6.33	6.33
Maximum	10.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
Min	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Standard deviation	1.68	1.31	1.24	1.31	1.34	1.31	1.37	1.37
Median	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Range	5.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Variance	2.82	1.72	1.54	1.73	1.79	1.73	1.88	1.88

Based on the findings regarding the CO concentration value in Kuala Lumpur around 5-8 ppm, the stations that recorded the highest average CO recorded in the city center zone were Station 1 (Dataran Merdeka), Station 2 (Asia Park), and Station 4 (Sunway Velocity). The average CO value at this station is high compared to other areas due to the increasing number of vehicles, especially in the city center. We know that the downtown area is the population's focus area, mainly carrying out daily activities that go down and back to work. In the morning the number of vehicles is lower than in the evening. Therefore, this causes the average CO to be below the night (1.00 AM- 4.00 AM). Following the findings by Talib et al. (2006), the CO value will increase starting at 7.00 AM when the road is congested and increases CO in the evening (Mohd Talib, Rozali, & Zaharizam, 2006). Stations with low CO concentration values ranging from 5 ppm to 6.12 ppm. This area includes Station 3 (Sri Utara), Station 6 (Jalan Kepayang), Station 7 (Damansara), Station 10 (Bukit Jalil Stadium), Station 11 (Tesco Cheras), and Station 12 (Sungai Besi Town). The average value of low CO concentrations at the station is due to the station's lack of vehicles. The higher the number of vehicles, the higher the CO concentration in the area.

CO concentration at day time

In the evening, the highest CO concentration value is still recorded at Station 4 (Sunway Velocity), with a CO concentration value reading of 14 ppm. The low value is recorded at Station 12 (Sungai Besi Town) with a CO concentration value reading of 7 ppm. The high CO concentration value of Station 4 is due to increased vehicles, especially during peak hours and return to work. Overcrowded conditions have contributed to CO elevations in areas where vehicles are moving slowly. Next, the low CO concentration value is recorded at Station 12 (Sungai Besi Town). Poor traffic conditions, to some extent, cause low CO value readings. The observation location is also a few meters away from the main road. Therefore the value at Station 12 is lower than the CO concentration value in other areas.

The main discussion topic in this chapter is the average CO in the evening at each station. Based on the Analysis done by the researcher found that the average concentration of CO value in the evening was in the range of 7.38 ppm - 13.7 ppm. There is a significant difference in CO concentration values for each day in each location. In the afternoon, areas with high CO concentration values were stations 1 (Dataran Merdeka) and 4 (Sunway

Table 4. Value of CO concentration during the day

Station	Day (PPM)							
	1	2	3	4	5	6	7	8
1	12.00	13.00	13.00	13.00	12.00	12.00	12.00	12.00
2	10.00	11.00	10.00	11.00	11.00	11.00	10.00	10.00
3	8.00	8.00	8.00	9.00	7.00	9.00	8.00	8.00
4	10.00	12.00	13.00	14.00	11.00	13.00	10.00	12.00
5	9.00	10.00	11.00	12.00	9.00	12.00	9.00	9.00
6	9.00	10.00	10.00	12.00	9.00	11.00	9.00	9.00
7	7.00	9.00	10.00	9.00	9.00	9.00	7.00	7.00
8	7.00	8.00	8.00	8.00	8.00	8.00	7.00	8.00
9	7.00	9.00	9.00	9.00	9.00	9.00	7.00	7.00
10	8.00	8.00	8.00	8.00	8.00	8.00	8.00	10.00
11	8.00	9.00	8.00	9.00	6.00	9.00	8.00	8.00
12	7.00	8.00	8.00	8.00	7.00	7.00	7.00	7.00
Average	8.50	9.60	9.70	10.20	8.80	9.80	8.50	8.90
Maximum	12.00	13.00	13.00	14.00	12.00	13.00	12.00	12.00
Min	7.00	8.00	8.00	8.00	6.00	7.00	7.00	7.00
Standard deviation	1.57	1.68	1.87	2.12	1.80	1.90	1.57	1.78
Median	8.00	9.00	9.50	9.00	9.00	9.00	8.00	8.50
Range	5.00	5.00	5.00	6.00	6.00	6.00	5.00	5.00
Variance	2.45	2.81	3.52	4.52	3.24	3.61	2.45	3.17

Velocity). The increase in the concentration of pollutant gas is closely related to traffic volume on the road. The vehicle's driving mode also affects the CO concentration rate, where the CO emission rate is high when the vehicle moves at a low-speed limit. Converting a vehicle's speed from low to high will result in a higher concentration of pollutant gas for CO than uniform driving. For example, traffic congestion on the Dataran Merdeka and the Sunway velocity routes has contributed to increased CO in the area (Nurul Bahiah, 2007).

Finally, CO overall averages at each station are still lower and do not exceed the standard limits of NAAQS and DOE, below 35 ppm and 30 ppm. Overall, the average in Kuala Lumpur is around 12.9 ppm to 20.7 ppm the night and day. The total CO concentration rotation in Kuala Lumpur, 12 stations, can be categorized into three levels where there are areas with low, medium, and high CO concentration values. However, the level of CO concentration in all areas is still below the standard set by the DOE for the overall average high CO concentration values recorded at Station 1 (Dataran Merdeka), Station 2 (Asia Park), and Station 4 (Sunway Velocity).

The average value of low CO concentration during the day was recorded at Station 3 (Sri Rampai), Station 7 (Damansara), Station 8 (Petron Bangsar), Station 9 (Standard Chartered), 10 (Bukit Jalil Stadium), Station 11 (Tesco Cheras) and Station 12 (Sungai Besi Town). The average value of CO concentration in this area is low due to the fewer vehicles in the area than in areas that focus on the population, especially the city center. The average concentration of values in this area is also due to the location's background factor. For example, Station 10 is the Bukit Jalil Stadium, where the lack of buildings that protect the road and the wind movement factor have reduced the area's concentration rate.

Several factors influence the increase in CO concentration in this area. Among them is the volume of traffic. The increase in pollutant gas concentration is closely related to the traffic volume on the road. Hickman's (1976) study proved the highest level of pollution recorded for the busiest roads. According to Bernama (2016), an average of three million vehicles are recorded daily in and out of the capital, with 58 percent being cars and 27 percent motorcycles. The rest are heavy vehicles, including buses and trucks. Due to this imbalance, almost 35 to 40 percent of vehicles are stuck in traffic jams during peak hours every day (Ukpebor et al., 2010).

Also, there is no denying that the rapid development factor in Kuala Lumpur is also a cause of traffic congestion. Next, low CO concentration

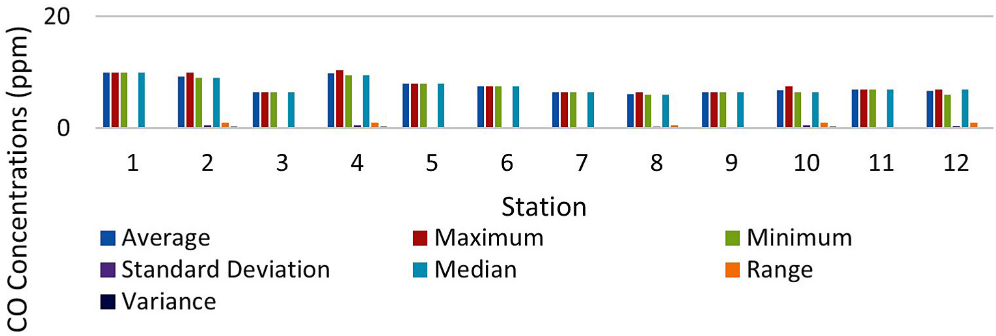

Figure 2. CO concentration by stations

values around 12.9 ppm - 15.3 ppm in total were recorded, namely Station 3 (Sri Rampai), Station 7 (Damansara), Station 8 (Petron Bangsar), Station 9 (Standard Chartered), Station 10 (Bukit Jalil Stadium), Station 11 (Tesco Cheras) and Station 12 (Sungai Besi Town). Several factors affect the average concentration value at the station is slightly lower compared to other stations. Among the factors is the location background. The background of the location influences the concentration of pollution. Lack of buildings protecting roads and wind movement factors will reduce CO concentration rates. For example, the Bukit Jalil Stadium area is extensive and airy. Traffic volume factors also affect the concentration of pollutant gases. The increase in the concentration of pollutant gas is closely related to traffic volume on the road. According to Nurul Bahiah (2007), it proves the busiest roads' highest gas pollution level.

CO Concentration by Sampling Stations

Figure 2 shows the descriptive values of CO concentrations by observation station at night. The CO value average of all stations is between 5-10 ppm. With majority showed values below 30 ppm. The highest value is ten ppm (Station 2). The lowest value is five ppm (Stations 3, 8, 10, 11, and 12). The standard deviation value is also not immense, with less than one indicating CO concentrations distributed evenly throughout Kuala Lumpur. This low value is due to the number of vehicles moving being small at observation time between 1 to 5 AM because it is not working hours.

CO concentration during weekdays

Working days for Kuala Lumpur are on Monday, Tuesday, Wednesday, Thursday, and Friday, as in Table 2. It assumes that vehicle usage is at the maximum level on working days. The average night CO concentration value is between 5-8.8 ppm, which is still below the DOE standard of 9 ppm for observation for 1 hour. The highest values are at stations 1 and 4 (9 ppm). Lowest values at Stations 3, 8, 10, 11, and 12 (5 ppm). Even the standard deviation shows a lower value. This value is still the same as the night value for the entire observation day due to the lack of vehicles on the road the night. CO concentrations on weekdays are between an average value of 7.6–12.60 ppm (Station 12-Station 1). The highest value is at Station 4 (12.6 ppm). The lowest value is at Station 11 (6 ppm). The standard deviation value is still not too far, around 0 to 1.30.

CO concentration on weekend

Fewer vehicles are found on the road during weekends or holidays on Saturdays and Sundays. On average, the night CO value is between 5-9 ppm. The highest average is nine ppm (Station 4), equivalent to the standard value by DOE. It is somewhat surprising based on the assumption that the lack of vehicles on the road contributes to CO's increase. The mean value obtained is at five ppm, and some stations have a minimum value equal to 9 ppm (Station 4). Two stations (2 and 4) show values above the DOE standard with ten and nine ppm values. The standard deviation indicates that most are at a value of 0 only.

On average, the evening CO value is between 7–12 ppm (Station 9 and Station 1). Most of the values are above seven ppm, with five stations showing values exceeding the DOE standard (Stations 1, 2, 4, 5, 6). The mean value indicates the value between 7–12 ppm. Each observation day's values are the same, even for Stations 1, 2, and 3. Five stations (Stations 1, 2, 4, 5, 6) show a high mean value beyond the DOE standard. Even the maximum value shows that the six highest stations (Stations 1, 2, 4, 5, 6, 10) are between 9–12 ppm.

CO concentration during workdays

The comparison CO concentration during day and night on working days is between 6.50 to 10.70 ppm. Three stations exceed the standard DOE (Stations 1, 2, 4). Most stations still show low values indicating that CO pollution in Kuala Lumpur is still under control. The mean value is between 5.5 to 10 ppm. The same station shows the highest value that passes the DOE standard (Stations 1, 2, 4). Compared to the maximum value, which shows a value between 6.5 to 11.50 ppm, five stations exceed the DOE standard (Stations 1, 2, 4, 5, 6). These values indicate consistency with only slight standard deviations.

CO concentrations in Kuala Lumpur vary on certain days. This difference in concentration is based on several factors, namely during working hours and not working hours. Working days are Monday through Friday. However, some companies work from Monday to Saturday, mostly workers from the private sector. During the working day, the value of CO concentration, especially during the day, is higher than at night. This concentration difference occurs when vehicle use at this time is high. According to Ashar and Rosliana (2018), the main road areas have high concentration because they are the vehicle's main route. The use of cars during working hours is maximum, especially in the morning, noon, and evening when workers return to their homes. During this working period, vehicles' movement is so high that it increases CO content in the evening (Mohd Talib, Rozali, & Zaharizam, 2006; Sendi, 2014; Azliyana et al., 2017). Compared to concentrations at night, working days recorded low CO concentration values as most people had returned to their respective homes to rest. Only a handful of people are still moving and working, for example, road construction workers and workers on duty at night, such as security guards and truck drivers who often move at night.

Also, roads close to bus stations, bus stands, and taxis have a high concentration level. This increase in concentration levels occurs because vehicles such as buses and taxis often pass through the area. Station 4 shows a high concentration level close to Sunway Velocity shopping mall. Furthermore, the station is the primary vehicle route in the dynasty-Maluri to the downtown area. Compared to night-time, even if the station is close to the mall or the main route, the concentration level becomes low because the vehicles' movement level at night is fewer. Every year, the ever-increasing number of vehicles significantly contributes to CO concentration in Kuala Lumpur during working hours. Because vehicles are one of the necessities for those who work, there is an increase in vehicle use demand. Most people use their vehicles to work due to the workplace's remote location, and no public vehicles pass through the area, so many workers choose to use their vehicles.

Simultaneously, the cost, comfort, and affordability of owning a vehicle have also increased cars' use during working hours. Since many workers use their vehicles to work, indirectly, the CO concentration level also increases during the working day. High CO concentrations occur in the morning when workers leave for work, at noon when they go out to eat, and in the evening when they return home. Many people in Malaysia own vehicles and motorcycles as their primary means of transportation. At the same time, other residents use public transport, such as MRT and LRT, to go to school or work every day (WHO, 2000; Sathitkunarat et al., 2006; Rozante, 2017; Ong, 2015; Khalilah, 2005).

CO concentration on weekend

The average value of CO during the day and night for non-working days in Kuala Lumpur ranges from 6.17 ppm to 10 ppm. Three stations record values above the DOE standard: Stations 1, 2, and 4. The mean value is between 6-10 ppm, with the same station showing the value exceeding the DOE standard (Stations 1, 2, 4). Even the same station is above the DOE standard for maximum value. As well as a slight standard deviation indicates the consistency of the data for each station.

CO concentrations on holidays are slightly different during working hours. This difference is due to only a handful of employees working on the day. CO concentration rates for all stations on holidays are associated with vehicle movement. The study results found that the concentration rate at some stations, on average, is 5–9 ppm. However, the concentration rate during the morning break is high at only two stations. It indicates that only two stations recorded higher readings in the morning than in the evening due to reduced traffic. Generally, working days are five days from Monday to Friday. However, several companies from the private sector have a working period of six days a week, from Monday to

Saturday. Because the average employee from the public sector is not working and the school is also on holiday, parents do not need data to pick up and send children or work. During non-working hours, Vehicle usage will be low as people choose to stay and rest at home. Most residents in the city will take the opportunity on holidays to get up late, do housework and fill more free time by resting at home only after five working days. However, some residents will go to work as usual, and vehicles will increase when the shopping malls start operating.

According to Noorsafiza et al. (2014), in their study on shopping malls' motives and attractions among Kuala Lumpur metropolitan visitors, three essential attractions influence customers' arrival at shopping malls in the city center convenience, image, and comfort physical shopping malls. Besides the supermarket's attraction, customers' main motive is also the main factor why vehicles' movement to the city center is increasingly high, namely the motive of a comfortable environment, entertainment, and social, and the third motive is the motive for finding utilities. However, some stations record high concentrations, such as Stations 1, 2, and 4. These stations are the main areas and central routes of the city. For example, Stations 1 and 2 are in the city center zone near residential (Taman Merdeka), shopping malls, and tourist attractions. Then, there is an increase in CO concentration in the area. The more movement of vehicles in the area, the higher the CO content released by the vehicle. While station four location on the Sunway Velocity route, Maluri, and Wangsa route. This route is a regular route to the city center and the public to the mall (Nurul Bahiah, 2007; Rafia et al., 2003).

According to the WHO, CO pollution happens worldwide, and most cities face similar issues, with car fuel consumption responsible for roughly 90% of all fuel (EPA, 2000; Straif et al., 2013). The results in Kuala Lumpur are similar to those in other cities. However, compared to London, Los Angeles, Sao Paulo, Rio de Janeiro, Mexico City, and even Mumbai, Kuala Lumpur's area is relatively small. Workers' vehicles come from outside Kuala Lumpur, such as Rawang (50 km from Kuala Lumpur) or Seremban (60 km from Kuala Lumpur), contributing to the CO concentration. On weekdays, the CO concentration is comparable to that of other major cities, while on weekends, it is lower. In contrast to other cities, CO concentrations in Kuala Lumpur were roughly the same as those found across cities in the United Kingdom in 1999, varying between 1.91 mgm^{-3} and 9.59 mgm^{-3} (Bush et al., 2001).

CONCLUSIONS

The result showed a significant increase in CO concentration in Kuala Lumpur. CO's significant concentration is mainly from the higher use of vehicles in urban areas such as Kuala Lumpur. Intervention includes maintaining public vehicles such as Light Rapid Transportation (LRT) to cover a most secluded urban areas as a long-time initiative to reduce the concentration. The intervention will help the commuter community build confidence in using public vehicles. People will need to educate not to use personal vehicles since the availability of public vehicles is blunt. People need to pursue public vehicles with some attraction from government agencies. With the help of the community and the government's work, CO will keep to lower concentration and maintain the people's health in the future.

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REFERENCES

1. Anwar Al-Mofleh, Soib Taib & Wael A. Salah. 2010. Malaysian energy demand and emissions from the transportation sector. Transport, 25(4), 448-453. DOI: 10.3846/ transport.2010.55.
2. Ashar Hasairin & Rosliana Siregar. 2018. Deteksi kandungan gas karbon monoksida (CO) hubungan dengan kepadatan lalu-lintas di Medan Sunggal, Kota Medan [Detection of carbon monoxide (CO) content in relation to traffic density in Medan Sunggal, Medan City]. The Journal of Biosciences, 4(1), 62-68.

3. Attorney General's Chamber (AGC). 2014. Federal Government Gazette. Environmental Quality (Clean Air) Regulations 2014. Putrajaya: Attorney General's Chamber. Retrieved from https://www.doe.gov.my/portalv1/wp-content/uploads/2015/01/Peraturanperaturan_kualiti_alam_sekeliling_udara_bersih_2014.pdf.
4. Azliyana Azhari, Ahmad Fariz Mohamed, & Mohd Talib Latif. 2016. Carbon emission from vehicular sources in selected industrial areas in Malaysia. International Journal of the Malay World and Civilisation, 4(1), 89–93.
5. Bernama. 2016. 3 juta kenderaan keluar masuk KL setiap hari – DBKL. The Malaysian Times. Retrieved from http://www.themalaysiantimes.com.my/3-juta-kenderaan-keluar-masuk-kl-setiap-hari-dbkl/.
6. Bush, T., Stedman, J. & Murrells, T. 2001. Projecting and mapping carbon monoxide concentrations in support of the air quality strategy review. Culham: AEA Technology Environment. Retrieved from https://uk-air.defra.gov.uk/assets/documents/reports/empire/aeat-env-r-0723.pdf.
7. Cernuschi, S., Giugliano, M. Cermin, A. & Giovannini, I. 1994. Model analysis of vehicle emissions factors. The Sci. of Total Environ., 169, 175-183.
8. Chameides W. L., & Walker J. C. G. 1973 A photochemical theory of tropospheric ozone. J. Geophys. Res., 78, 8751–8760.
9. Clearbaux, C., Edwards, D.P., Deeter, M., Emmons, L., Lamarque, J., Xue, X. T., Massie S.T., & Gille, J. 2008. Carbon monoxide pollution from cities and urban areas observed by the Terra/MOPITT mission. Geophysical Research Letter, 35, L03817. doi:10.1029/2007GL032300.
10. Department of Environment (DOE). 1996. Laporan keadaan kualiti alam sekeliling peringkat negeri-negeri [State-level environmental quality state report]. Kuala Lumpur: Kementerian Sains, Teknologi dan Alam Sekitar. (In Malay)
11. Department of Environment (DOE). 2013. Kementerian Sumber Asli dan Alam Sekitar : Garis Panduan Kualiti Udara Malaysia [Ministry of Natural Resources and Environment: Malaysian Air Quality Guidelines]. Retrieved from http://www.doe.gov.my/portalv1/wp-content/uploads/2013/06/Terjemahan-Slide-API_Kesihatan_Portal.pdf.
12. Dewan Bandaraya Kuala Lumpur (DBKL). 2008. Draf Pelan Bandar Raya Kuala Lumpur 2020, Jilid 1 Menuju Ke Arah Bandar Raya Bertaraf Dunia (1st ed.) [Draft Kuala Lumpur City Plan 2020, Volume 1 Towards a World Class City (1st ed.)]. Kuala Lumpur: Pencetakan Nasional Malaysia Berhad. (In Malay)
13. Directorate-General for Internal Policies Policy Department A: Economic and Scientific Policy. 2016. Comparative study on the differences between the EU and US legislation on emissions in the automotive sector. Brussels: Policy Department A: Economic and Scientific Policy. Retrieved from https://www.europarl.europa.eu/RegData/etudes/STUD/2016/587331/IPOL_STU(2016)587331_EN.pdf
14. Ehhalt D.H. 1999. Gas phase chemistry of the troposphere. In Global aspects of atmospheric chemistry, topics in physical chemistry (Ed. R. Zellner), vol. 6, 21–109. Darmstadt: Springer.
15. Environment Protect Agency (EPA). 2010. Health, environment, and climate impacts. Retrieved from http://www3.epa.gov/airtrend/2010/report/airpollution.pdf.
16. Environmental Quality Act. 1974. Akta 127 & Peraturan-Peraturan dan Perintah-Perintah [Act 127 & Regulations and Orders]. Kuala Lumpur: International Law Book Services. (In Malay)
17. EPA. 2000. National Air Quality and Emissions Trends Report, 1998. Research Triangle Park, NC: United States Environmental Protection Agency (EPA 454/R-00-003).
18. Hickman, A. J. 1976. Atmospheric pollution measurement in west London. TRRL Laboratory Report 709, Environment Division, Transport Department, TRRL, Crowthorne, Berkshire, England.
19. Ideriah, T. J. K. 2008. Effect of lamp on levels of air pollution in Port Harcourt, Nigeria. Journal of Applied Science, 3(1), 70–80.
20. Industrial Accident Prevention Association (IAPA). 2003. Carbon monoxide in the work places. Retrieved from http://www.iapa.ca/pdf/carbon_monoxidefeb2003.pdf.
21. Junaidi Awang Besar, Rosmadi Fauzi, Amer Saifude Ghazali, Hazim Abdul Ghani & Zainun Abidin Baharum. 2017. Kuala Lumpur dan cabaran baru pembangunan berterusan (Kuala Lumpur and the new challenges of continuous development). Geografia Malaysian Journal of Society and Space, 10(6), 75-85.
22. Khalilah Kamaruddin. 2005. Permodelan kepekatan karbon monoksida di Bulatan Utama di Bandaraya Kota Kinabalu (Perisian Permodelan CALRoad) [Modeling of carbon monoxide concentration in the Main Circle in Kota Kinabalu City (CALRoad Modeling Software)]. Universiti Malaysia Sabah. (In Malay)
23. Kho, F.W.L, Law, P.L, Ibrahim, S.H., & Sentian, J. 2007. Carbon monoxide levels along roadway. International Journal of Environmental Science and Technology, 4(1), 27–34.
24. Lelieveld, J., Thompson, A. M., Diab, R. D., Hov, O., Kley, D., Logan, J. A., Nielson, O. J., Stockwell, W. R., & Zhou, X. 1999. Tropospheric ozone and related processes. In Scientific assessment of ozone

depletion: 1998 (Ed. D. Albritton). Geneva: World Meteorological Organization, 8.1–8.42.

25. Levy, H. 1971 Normal atmosphere: Large radical and formaldehyde concentrations predicted. Science 173, 141–143.
26. Mohd Talib Latif, Mohamed Rozali Othman, & Zaharizam Johnny. 2006. Kajian kualiti udara di bandar Kajang, Selangor [Air quality study in Kajang city, Selangor]. The Malaysian Journal of Analytical Sciences, 10(2), 275-284.
27. Nafhatun Amirah Azri. 2016. Kajian ke atas kualiti udara dalaman koc tren bagi perkhidmatan monorel dan komuter [A study on the indoor air quality of train coaches for monorail and commuter services]. Retrieved from http://eprints.uthm.edu.my/8852/1/nafhatun_amirrah_binti_mohamed_azri.pdf. (In Malay)
28. Nasir Nayan, Mohmadisa Hashim, Yazid Saleh, Hanifah Mahat, Madeline Henry Luyan & Liusteh Mikol. 2020a. Urban land surface temperature variability in Kuala Lumpur City, Malaysia. Test: Engineering and Management, 83(May-June), 24120-24137.
29. Nasir Nayan, Mohmadisa Hashim, Yazid Saleh, Hanifah Mahat, Madeline Henry Luyan & Nur Suhaila Mohd Zaki. 2020b. Spatial variation of tropical urban dioxide concentration: A case study of Kuala Lumpur. International Journal of Psychosocial Rehabilitation, 24(8), 9049-9074.
30. National Research Council. 2002. The ongoing challenge of managing carbon monoxide pollution in Fairbanks, Alaska: Interim Report. Washington, DC: The National Academies Press. https://doi.org/10.17226/10378.
31. Noorsafiza Mohd Sapie, Mohd Yusof Hussain, Suraiya Ishak, Abd Hair Awang, & Novel Lyndon. 2014 Motif dan daya tarikan pusat membeli-belah dalam kalangan pengunjung metropolitan Kuala Lumpur, Malaysia [Motives and attractions of shopping malls among visitors to the metropolitan area of Kuala Lumpur, Malaysia]. Geografia Malaysian Journal of Society and Space, 10(1), 70-77. (In Malay)
32. Nurul Bahiah Nor. 2007. Analisis pencemaran udara (gas) yang dilepaskan oleh kenderaan bermotor di kawasan bandar : Kajian kes di Bandaraya Kuala Lumpur [Analysis of air pollution (gas) emitted by motor vehicles in urban areas: A case study in Kuala Lumpur City]. Retrieved from https://doi.org/10.1017/CBO9781107415324.004. (In Malay)
33. Ong, P. T. 2005. Permodelan kepekatan karbon monoksida di jalan-jalan utama di pusat bandar Kota Kinabalu [Modeling of carbon monoxide concentrations on major roads in Kota Kinabalu city center]. Sabah: Universiti Malaysia Sabah. (In Malay)
34. Prather, M., Ehhalt, D., Dentener, F., Derwent, R., Dlugokencky, E., Holland, E., Isaksen, I., Katima, J., Kirchhoff, V., Matson, P., Midgley, P., & Wang, M. 2001. Atmospheric chemistry and greenhouse gases. In Climate change 2001: The scientific basis (ed. J. T. Houghton). New York: Cambridge University Press.
35. Prinn, R. G., Huang, J., Weiss, R. F., Cunnold, D. M., Fraser, P. J., Simmonds, P. G., McCulloch, A., Harth, C., Salameh, P., O'Doherty, S., Wang, R. H. J., Porter, L., & Miller, B. R. 2001. Evidence for substantial variations of atmospheric hydroxyl radicals in the past two decades. Science, 292, 1882–1888.
36. Prinn, R. G. 2003. Ozone, hydroxyl radical, and oxidative capacity. In Treatise on Geochemistry, Heinrich D. Holland & Karl K. Turekian (Ed. in Chief), Vol. 4, 1-19. Massachusetts: Elsevier Ltd.
37. Rafia Afroz, Nasir Hassan, & Noor Akma Ibrahim. (2003). Review of air pollution and health impacts in Malaysia. Environmental Research, 92(2), 71–77. Retrieved from https://www.researchgate.net/publication/260888032_Review_of_air_pollution_and_health_impacts_in_Malaysia.
38. Rozante, J. R., Rozante, V., Alvim, D. S., Manzi, A. O., Chiquetto, J. B., D'Amelio, M. T. S., & Moreira, D. S. 2017. Variations of carbon monoxide concentrations in the Megacity of São Paulo from 2000 to 2015 in different time Scales. Atmosphere, 8(5), 81. https://doi.org/10.3390/atmos8050081.
39. Sathitkunarat, S., Wongwises, P., Pan-Aram, R., & Zhang, M. 2006. Carbon monoxide emission and concentration models for Chiang Mai urban area. Advances in Atmospheric Sciences, 23(6), 901–908. https://doi.org/10.1007/s00376-006-0901-9.
40. Sendi Yulianti. 2014. Analisis konstrasi gas karbon monoksida (CO) pada ruas jalan Gajah Mada Pontianak. [Analysis of carbon monoxide (CO) gas construction on Gajah Mada Pontianak road section]. Jurnal Teknologi Lahan Basah, 1(1), 1–10. (In Indonesia)
41. Straif, K., Cohen, A., & Samet, J (Ed.). 2013. Air pollution and cancer. Geneva: WHO Press, World Health Organization.
42. Ukpebor, E. E., Ukpebor, J. E., Eromomene, F., Odiase, J. I., & Okoro, D. 2010. Partial and diurnal variations of carbon monoxide (CO) pollution from motor vehicles in an urban centre. Polish Journal of Environmental Studies, 19(4), 817-823.
43. Werk, K., Warner, C.C., & Davis, W. 1998. Air pollution its origin and control (3rd ed.). United States: Addison Wesley Longman.
44. World Health Organisation (WHO), Regional Office for Europe. 2000. Air quality guidelines (2nd. ed). Copenhagen: World Health Organisation.
45. Yusri Yusup, Mardiana Idayu Ahmad, & Norli Ismail. 2014. Indoor quality of typical Malaysian open-air restaurants. Environment and Pollution, 3(4), 10–23.
46. Zennetti, P. 1990. Air pollution modeling: Theories, computational method, and available software. United Kingdom: Computational Machines Publications.