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Comparison of O_3, NO, NO_2 concentrations and meteorological parameters in urban, sub urban and rural residential area

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Abstract

Ozone (O_3) have many adverse impacts toward the living human, environment and O_3 formed through the photochemical reaction with the aid of sunlight. Therefore, this study focused on the determination of O_3, nitric oxide (NO), nitrogen dioxide (NO_2) concentrations and meteorological parameters (temperature, humidity, wind speed and wind direction) three residential area namely Taman Tun Dr Ismail Jaya, Selangor as the urban area, Taman Delima, Sungai Petani, Kedah as the sub urban area and Taman Kifayah, Jeli, Kelantan as the rural area. The monitoring were continuously done for three days in 24 hours from 12 a.m. until 12 a.m. per day at each site. Aeroqual S500 series and weather station model RK900-01 were used to measure O_3, NO, NO_2 concentrations and meteorological parameters. The concentration of O_3, NO, NO_2 and the meteorological parameters were determined and O_3 concentration was compared by one-way analysis of variance (ANOVA). Among the studied areas, the highest mean O_3 concentration was recorded in Taman Delima, Sungai Petani with 35.2 ppb followed by Tun Dr Ismail Jaya with 33.3 ppb. Result suggested that sub urban areas showed higher mean O_3 concentration compared to urban area which might linked to the availability of the O_3 precursors in the area. As expected, the lowest mean O_3 concentration recorded at Taman Kifayah, Jeli with 12.1 ppb as the area have limited O_3 precursor's sources. However, the ozone concentration at three residential areas were still under permissible level according to Recommended Malaysia Ambient Air Quality Guidelines (RMAAQ).

1. INTRODUCTION

Air pollution can be defined as the presence in the atmosphere of one or more contaminants in such quantities and for such duration as is injurious or tends to be injurious, to human health, human welfare, animal or plant life and the environment (Latif *et al*., 2012; Singal, 2012; Awang *et al*., 2018). Atmospheric pollution is caused by both natural and anthropogenic sources. The natural sources of natural air pollution are volcanoes, biological decay and forest fires.

Ozone (O_3) is one of the air pollutants that being proven causes several issues. The gas is made up of three atoms of oxygen which is abundantly found in the layer of the stratosphere is called ozone layer. Ground level ozone is a secondary pollutant that gives bad effect to health to living organisms that found in the ambient air in Malaysia. Ozone is indirectly produced from anthropogenic activities which are the motor vehicles, traffic and combustion of fuels. The formation of O_3 in the troposphere happen when an atom of ozone combines with molecular oxygen by solar photo-dissociation of nitrogen dioxide (NO_2) and precursor emissions of volatile organic compound (VOCs) which is known as O_3 photochemical reactions. Ozone is also the main component of smog and photochemical oxidant and also considered as a secondary pollutant (Latif *et al*., 2012; Banan *et al*., 2013; Awang *et al*., 2015). As reported by various researchers, O_3 was identified as the most significant secondary air pollutants in Malaysia (Shith *et al*., 2020) and many parts of the world. These secondary pollutants also included as criteria air pollutants listed in Recommended Malaysia Ambient Air Quality Guidelines (RMAAQ). As a criteria pollutant, O^3 can affect health in many ways. However, the most prominent effect of inhaling O_3 pollutants over period of time can cause respiratory problem that interfere the lung function and cardiovascular disease (Brunekreef and Holgate, 2002).

Nitrogen oxides (NO_x) is undeniably the most important O_3 precursors in urban or sub urban areas. Awang *et al*. (2015) reported that NO_2 photolysis and NO titration are the important reactions that governed and controlled O_3 concentrations. These two reactions will be determined either in production or destruction periods. The emission of the NO_x generally originates from either natural or anthropogenic sources. The main natural source that produced NOx is lightning, while anthropogenic emission from motor vehicle and industrial activities were

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identified as the main sources of NO_x. In consequently, high NO_x concentrations always been associated with urban and sub urban environment in which high density of motor vehicles are reported. Whereas, rural area with significantly lower population and minimize congestion was most likely have lower NO_x concentrations, thus avoiding O_3 pollutions.

Other than precursors, meteorological parameters are temperature, wind speed, wind direction and relative humidity greatly influence the concentration of O_3 produced in the air. The meteorology parameters known to regulating the formation, dispersion, transport and dilution of O_3 concentration at any given locations (Toh *et al*., 2012). The meteorological condition varies at different places due to topographic and weather conditions. Ozone formation is enhanced during hot and high in temperature (Kgabi and Sehloho, 2012) as sunlight is the main catalyst for O_3 photochemical reactions. Meanwhile, during the high relative humidity conditions or rainfall events, O_3 is significantly wash out from the ambient air, thus reducing it to lower concentration (Awang *et al*., 2015).

The aim of this study is to investigate variations of O3, with its main precursors which are NO, NO2 concentrations and meteorological parameters i.e temperature, relative humidity and wind speed in residential areas located urban, sub urban and rural in Malaysia.

2. MATERIALS AND METHODS

2.1 Study area

This research was conducted at three different residential areas based on municipality criteria. Taman Tun Dr Ismail Jaya in Shah Alam, Selangor is classified as urban areas, Taman Delima Bakar Arang, Sungai Petani, Kedah is classified as sub urban area and Taman Kifayah, Jeli Kelantan is located in rural areas. The specific location of the study areas shown in Figure 1 and Figure 2.

Figure 1: Location of study areas in Peninsular Malaysia

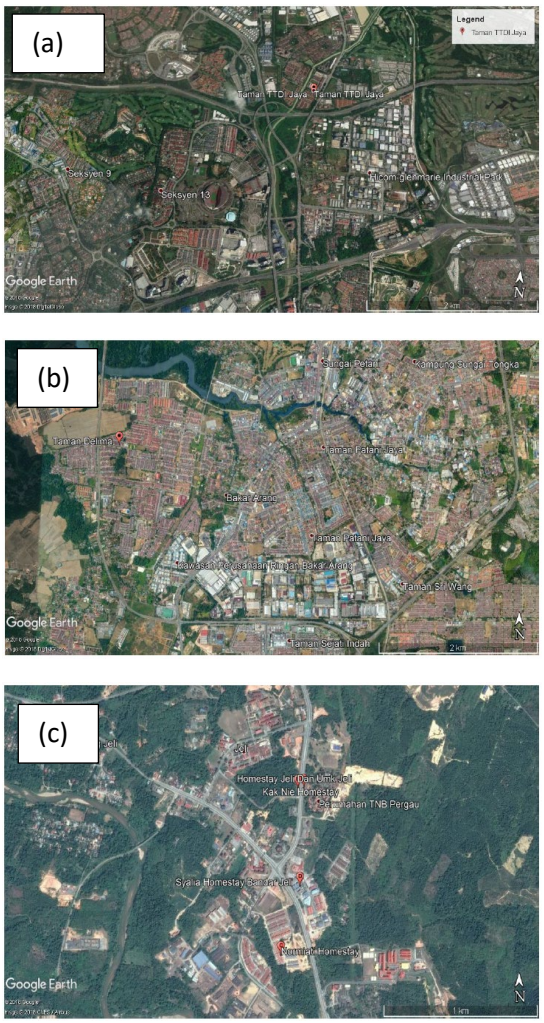

Figure 2: The location of study areas through satellite image representing (a) Taman Tun Dr Ismail Jaya, urban area (b) Taman Delima, sub-urban area (c) Taman Kifayah, rural area

2.2 Data Acquisition

The data were obtained by monitoring is the ozone, nitrogen oxide, temperature, humidity and the wind speed or wind direction. Specific instruments were used to collect the data. The monitoring data were collected for 24 hours in 3 days period.

For the ground level ozone, the model Aeroqual Series 500 was used to collect the ozone concentrations. Aeroqual Series 500 is a portable air quality monitor that been used to collect the monitoring data of outdoor air pollutants and have a plug-in sensor for collecting temperature and humidity data. The maximum record for data stored by the series is 8,188 records. The accuracy of the sensor is 0.01 parts per million in response time of 5 seconds. The range for the temperature recorded is 0ºC until 40ºC.

The concentration of O_3 precursors, nitrogen dioxide was collected using Aeroqual Series 500 for both residential areas. This instrument is both fixed and portable and designated to measure the concentrations then gain the exposure towards human and living organisms in one area. Aeroqual Series 500 is a portable air quality monitor that

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was used to obtain the monitoring data which can be used in wide area air quality surveys.

Weather station model RK900-01 was used to evaluate the typical trends and measured the ozone concentration and it precursors, NO/NO_2. The equipment has been used to record the meteorological parameters which consist of humidity, temperature and the wind speed or wind direction.

2.3 Data Analysis

Several techniques were used to analyse data. The concentration of O_3, NO, NO_2 and the meteorological parameters were determined and O_3 concentration was compared by one-way ANOVA. One-way ANOVA is the one-way analysis of variance that determine significance difference between two or more independent groups. However, two- sample t-test to three or more samples being generalizes by the one-way ANOVA (Heiberger and Neuwirth, 2009). One-way ANOVA is required since its involved three residential areas which is more than two groups (Ross and Willson, 2017).

3. RESULTS AND DISCUSSION

3.1 Difference Concentration Levels

The variation concentrations of ozone and nitrogen dioxide of 24 hours in three days in three different respective residential areas were illustrated in box plot and descriptive statistics. Descriptive statistics used to obtain mean, standard deviation, the maximum and minimum value of the data in three residential areas Table 1 to Table 3. The variation of the concentration for O_3 and nitrogen dioxide NO_2 were displayed using box plot in shown in Figure 3 to Figure 5.

Table 1: Descriptive analysis of urban residential area, Taman Tun Dr Ismail Jaya

Parameter	Day 1				Day 2				Day 3			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
O_3 (ppb)	30.3	21.7	0.0	72.0	33.3	30.9	0.0	73.0	28.1	22.6	0.0	62.0
NO_2 (ppb)	40.6	12.9	15.0	62.0	39.3	17.6	15.0	75.0	35.0	12.8	16.0	53.0
VOC (ppm)	2.1	0.6	1.3	3.3	2.8	1.5	1.0	5.7	2.1	0.9	1.0	3.8
Temp. (°C)	28.3	3.1	25.0	34.0	28.9	4.0	24.0	35.0	29.7	3.6	25.0	36.0
RH (%)	64.1	13.4	45.3	86.4	69.6	15.5	46.7	87.5	66.4	13.4	45.1	84.3

Table 2: Descriptive analysis of sub urban residential area, Taman Delima, Bakar Arang

Parameter	Day 1				Day 2				Day 3			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
O_3 (ppb)	25.1	27.7	0.0	73.0	35.2	23.2	0.0	72.0	24.1	14.6	0.0	53.0
NO_2 (ppb)	46.6	8.4	28.0	58.0	38.4	8.4	25.0	53.0	40.4	6.8	26.0	53.0
VOC (ppm)	9.3	2.0	6.5	12.1	5.8	1.4	3.9	8.9	4.5	1.3	3.0	8.1
Temp. (°C)	28.8	3.5	25.0	34.0	29.5	2.8	26.0	34.0	28.3	1.8	26.0	33.0
RH (%)	71.7	11.3	54.8	84.8	68.2	9.6	51.0	80.3	73.1	7.4	55.3	80.4

Table 3: Descriptive analysis of sub urban residential area, Taman Kifayah, Jeli

Parameter	Day 1				Day 2				Day 3			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
O_3 (ppb)	12.1	11.1	0.0	29.0	14.0	12.7	0.0	34.0	14.6	11.6	0.0	30.0
NO_2 (ppb)	46.3	8.2	28.0	65.0	43.0	7.6	29.0	59.0	42.9	9.6	24.0	64.0
VOC (ppm)	6.1	4.4	2.0	17.0	5.3	1.9	2.8	9.3	4.7	2.0	2.3	9.9
Temp. (°C)	28.5	4.2	23.0	36.0	28.9	4.5	23.0	36.0	28.9	4.1	24.0	36.0
RH (%)	67.0	12.8	45.6	81.8	65.4	13.2	45.4	81.6	66.7	12.7	44.8	81.7

*SD = standard deviation RH = relative humidity

The results show that the mean of ozone concentrations in Taman Tun Dr Ismail Jaya in three days were 30.3 ppb, 33.3 ppb and 28.1 ppb respectively. Among three days, second day shows the highest mean ozone concentration. Meanwhile, the mean of nitrogen dioxide concentrations on the first day is the highest with 40.6 ppb and 39.3 ppb and 35.0 ppb, respectively for the following days.

As for the sub urban residential area, Taman Delima, Bakar Arang, the mean ozone concentrations were 25.1 ppb, 35.2 ppb and 24.1 ppb. The mean of ozone concentration showed the highest on the second day compared to the other day. The mean concentrations of nitrogen dioxide were 46.6 ppb, 38.4 ppb and 40.4 ppb respectively in duration of three days. The highest mean showed on the first day compared to the other days.

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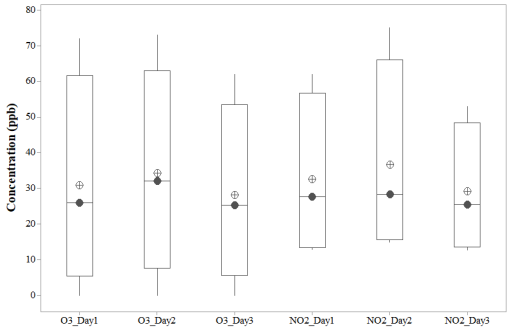

Figure 3: Box plot for the concentration of O_3 and NO_2 at Tun Dr. Ismail, Shah Alam

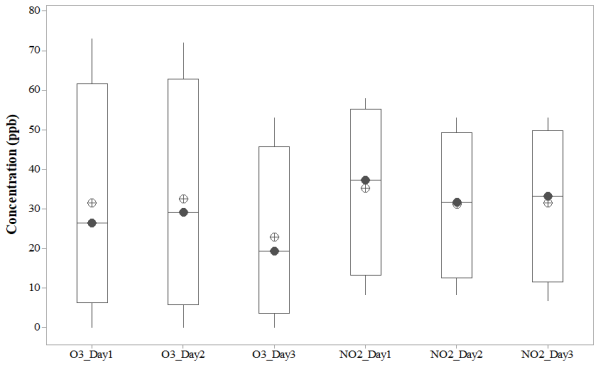

Figure 4: Box plot for the concentration of O_3 and NO_2 at Taman Delima, Bakar Arang

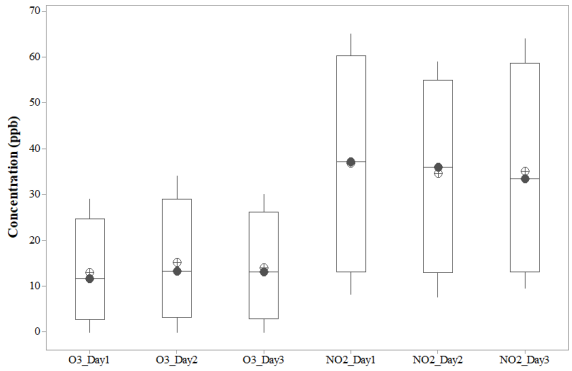

Figure 5: Box plot for the concentration of O_3 and NO_2 at Taman Kifayah, Jeli

Taman Kifayah, Jeli in Kelantan is the rural residential area in this study. The mean ozone concentrations in three days were 12.1 ppb, 14.0 ppb and 14.6 ppb respectively. Meanwhile the mean concentrations of nitrogen dioxide are 46.3 ppb, 43.0 ppb and 42.9 ppb, respectively for three days. In this residential area, the third day show the highest mean of ozone concentration compared to the first day and the second day. However, the mean of nitrogen dioxide concentration is the highest on the first day.

The mean concentration of ozone showed the highest in urban residential area compared to the sub urban and rural residential areas. The urban residential area, Taman Tun Dr Ismail Jaya showed the highest mean of ozone concentration with 33.3 ppb on second day while the lowest mean of ozone concentration is in the rural residential area, Taman Kifayah, Jeli with 12.1 ppb on the first day. All ozone and nitrogen dioxide concentrations studied were below the Malaysian Ambient Air Quality Guidelines for 1-hour averaging time which is 0.01 ppm or 100 ppb for mean concentration while 0.17 ppm or 170 ppb for 1- hour averaging time for mean nitrogen dioxide concentrations.

Overall, Taman Tun Dr. Ismail Jaya recorded the highest mean ozone while the lowest mean ozone is recorded in Taman Kifayah. The maximum concentration of ozone recorded both at Taman Tun Dr. Ismail Jaya and Taman Delima (73.0). The value might be because of the emission of the vehicles into the atmosphere and the activity from the industrial near to the both residential areas. Taman Delima is the sub urban residential area which have heavy industrial activity in the area. This is one of the factors of the maximum ozone in this residential area. The obtained result was inclined with previous study (Latif *et al*., 2012; Banan *et al*., 2013) which associated high O_3 concentration with high anthropogenic emissions driven by various economic sectors. Sungai Petani and Shah Alam are known as major industrial location in Peninsular Malaysia which home to many economic activities. The expansion of economic activities would create many job opportunities, thus significantly increase the population in the surrounding areas. These areas also prone to experience heavy traffic and daily congestion which automatically increase the emission of NOx that later could photochemical turned in O_3. Conversely. Lower O_3 concentration measured in Jeli reflected the area as Jeli is considered as new township with low population.

3.2 Comparison of ground level ozone of the residential areas

One-way analysis of variance (ANOVA) was carried out to compare the means of ozone concentration in three different residential areas which are Taman Tun Dr Ismail Jaya in Shah Alam, Taman Delima in Bakar Arang and Taman Kifayah in Jeli.

Table 4 showed the result of the one-way ANOVA of O_3 concentrations. The mean of the ozone concentration are proven to have different value to each areas if the p – value obtained less than 0.05 which translate to 95% confidence intervals. The p – value obtained was 0.00. Since the p – value obtained was less than 0.05, there were significance difference in the ozone concentration between the residential areas.

The comparison between the residential areas were shown in Table 5. The p-value of comparing the area between Taman Delima, Bakar Arang and Taman Tun Dr Ismail Jaya were 0.04. The p-value is less than 0.05 indicated that there is significance difference in the ozone concentration among the residential areas. The p-value for comparing Taman Delima, Bakar Arang and Taman

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Kifayah, Jeli or Taman Kifayah, Jeli and Taman Tun Dr Ismail Jaya, Shah Alam were 0.00 which were also less than 0.05. Hence, it is also indicating that there was significance between the residential areas.

Table 4: One-way ANOVA of O_3 concentrations

	Mean Square	F	p-value
Between groups	9759.03	30.80	0.00
Within groups	316.90		
Total			

Table 5: Multiple Comparison O_3 concentration of three residential areas (Turkey HSD)

(I) Station	(J) Station	p-value	95% Confidence Interval	
			Lower bound	Upper bound
Bakar Arang	Shah Alam	0.04	-16.18	-0.377
	Jeli	0.00	9.56	24.80
Shah Alam	Bakar Arang	0.04	0.37	16.18
	Jeli	0.00	17.56	33.36
Jeli	Bakar Arang	0.00	-24.80	-9.56
	Shah Alam	0.00	-33.36	-17.56

4. CONCLUSION

The result of this study showed the diferences concentration of ozone in three different residential areas consist of Taman Tun Dr Ismail Jaya, Taman Delima and Taman Kifayah. The highest mean of ozone concentration was recorded on the second day in Bakar Arang (35.2 ppb) due to open burning of paddy field while the lowest mean was recorded on the first day (12.1 ppb) in Jeli. However, ozone concentration in Shah Alam was the highest averagely. The mean of the ozone concentration in the 24 hours duration in three days were proven to be different among the residential areas if the p-value obtained less than 0.05. The result of one-way ANOVA showed the p-value were less than 0.05 which mean that there is significance difference. Result suggested that, variation in O3 concentration were most likely influenced by its precursors (NO_2), while, the effect of meteorological parameters was considered as minimum.

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