IOP Conf. Series: Materials Science and Engineering **374** (2018) 012097 doi:10.1088/1757-899X/374/1/012097

Variation of Ground-Level Ozone Concentration in Urbanized Area in Malaysia

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Abstract. The study focused on ground level ozone concentration in 3 selected urbanized areas in Malaysia that are Shah Alam, Ipoh, and Malacca. The main objective of this study is to determine the correlation between the ozone concentration, air pollutant and meteorological parameters. First, the surface ozone concentration was characterised to observe the variation of ozone concentration in the studied areas. The diurnal variation of ozone in all selected urbanized area is characterized by low concentration during early morning and late night and high concentration during day time.The average ozone concentrations are below the limit (0.1 ppm) of Malaysian Ambient Air Quality Guideline permissible level, however high hourly concentration were recorded during the day especially at 1.00 p.m. to 4.00 p.m. The correlation coefficient between ozone and the various meteorological parameters were weak except for certain pollutantssuch as NO2, NOx and CO.

1. Introduction

Ground-level ozone is one of a major source of air pollutant in a few urban areas on the world. Ground level ozone is produced by a progression of responses, under the influenced of sunlight, including volatile organic compound (VOCs) consolidated with nitrogen oxides (NOx). Aggregately, NOx and VOCs are known as ozone precursors [1].Ozone is a secondary photochemical pollutant that is not contaminating in its own right. Oxide of Nitrogen and Non-methane Hydrocarbon are created from anthropogenic precursor resulting from vehicle and industry. That why it is hard to predict and control the presence of ozone [1]. Ozone concentration can change at various time from year to year.

Ozone formation can be created by the changing in climate condition (particularly in hot sunny days), such as periods of air stagnation, wind patterns, and other factors [2]. Ozone formation (O_3) is intensely influenced by daylight and temperature. The effect from temperature is associated with daylight where the meteorological conditions correlated with the formation of pollutant [2]. The statistical analysis will be carried out to analyze the ozone concentration with its precursors as well as meteorological parameters so that the thorough understanding about the characteristics of ozone concentration at the study areas can be evaluated.

2. Material and methods

Data of air quality for Shah Alam, Ipoh, and Malacca was collected over five years (2008- 2012) from Department of Environment (DoE), Malaysia. The data will be sort, analysis, and make comparison on the previous study. The test such as descriptive statistic, box plot, and time series plot was carried out to assess the characteristic of surface ozone concentration in these selected urban area, the diurnal plot to evaluate the correlation between ozone and its precursor, Pearson correlation and backward trajectories to evaluate the correlation between ozone concentrations with meteorological parameter. The Statistical Package Social Science (SPSS) Software and Microsoft Office Excel are used to analyze the data. This study was carried out to identify the pattern, shape, dispersion and the distribution of the dataset.

3. Results and discussion

3.1. The Descriptive Statistics

Table 1 shows the descriptive statistic for ozone concentration in three urbanized area. From the mean, the ozone concentrations for Shah Alam, Ipoh, and Malacca are below the limit (0.1 ppm) as stipulated in Malaysian Ambient Air Quality Guidelines (MAAQG). The descriptive statistics of ozone concentration also indicate that the median are less than mean. The higher the mean than median values, the distribution will be skewed to the left. Standard deviation is gained from square root of the variance and will show how long the distribution of the data is.

Table 1. Descriptive statistic of ozone concentration in three urbanized areas.

Descriptive Statistic								
Location	Year	Mean	Median	Std. Deviation	Skewness	Range	Min	Max
Shah Alam	2008	0.0197	0.0080	0.0237	1.5390	0.1500	0	0.1500
	2009	0.0208	0.0110	0.0234	1.4660	0.1500	0	0.1500
	2010	0.0190	0.0080	0.0231	1.4210	0.1500	0	0.1500
	2011	0.0178	0.0080	0.0217	1.5360	0.1600	0	0.1600
	2012	0.0168	0.0080	0.0196	1.3750	0.1200	0	0.1200
Ipoh	2008	0.0154	0.0090	0.0170	1.4800	0.1100	0	0.1100
	2009	0.0151	0.0090	0.0167	1.4750	0.1000	0	0.1000
	2010	0.0153	0.0090	0.0158	1.4740	0.1600	0	0.1600
	2011	0.0148	0.0090	0.0158	1.3820	0.1000	0	0.1000
	2012	0.0167	0.0100	0.0169	1.2890	0.1000	0	0.1000
Malacca	2008	0.0174	0.0150	0.0143	0.8670	0.0800	0	0.0800
	2009	0.0189	0.0160	0.0157	0.9680	0.1200	0	0.1200
	2010	0.0188	0.0150	0.0160	1.0540	0.1400	0	0.1400
	2011	0.0202	0.0170	0.0162	0.9300	0.1000	0	0.1000
	2012	0.0203	0.0170	0.0156	0.7840	0.0800	0	0.0800

Hourly mean O_3 concentration in Shah Alam for 2008 to 2012 was around 0.0197 ppm, 0.0208 ppm, 0.0190 ppm, 0.178 ppm, and 0.0168 ppm respectively. These values were lower than the annual O_3 guidelines value of 0.06 ppm (8h-averaging times). However, maximum hourly O_3 concentrations from 2008 to 2012 were 0.15 ppm, 0.15 ppm, 0.15 ppm, 0.16 ppm, and 0.12 ppm respectively. These values were higher than the guideline which are 0.1 ppm (1h-averaging time).

O_3 concentration in Ipoh for 2008 to 2012 is in the range of 0.11 ppm, 0.10 ppm, 0.16 ppm, 0.10 ppm, and 0.10 ppm respectively. Meanwhile, for Malacca 2008 to 2012, the O_3 concentrations are in the range of 0.80 ppm, 0.12 ppm, 0.14 ppm, 0.10 ppm, and 0.08 ppm respectively. However, maximum O_3 concentrations in Ipoh were exceed the limit of MAAQG while O_3 concentration in Malacca is exceed the MAAQG except for 2008 and 2012.

3.2. Diurnal Fluctuations of Ozone and Its Precursors

The diurnal variations in air pollutants are related to those in meteorological conditions. Diurnal plot for Shah Alam, Ipoh, and Malacca was plotted according to the data set from 2008 to 2012. Figure 1 show the diurnal plot of ozone and its precursors (NOx and NMHC). There are also have some missing data for NMHC and NOx for Shah Alam and Malacca.

The diurnal variation of ozone in all selected urbanized area shows the almost same pattern are characterized by low concentration during early morning and late night and high concentration during day time. In other hand, NOx and NMHC show opposite pattern to ozone. It's characterized by low concentration during daytime but have a higher concentration during early morning and night time. The increasing of ozone concentration is corresponding to the decreasing of concentration of its precursors. The similar diurnal pattern in O_3 and precursors was observed in numerous urban areas around the world [3].

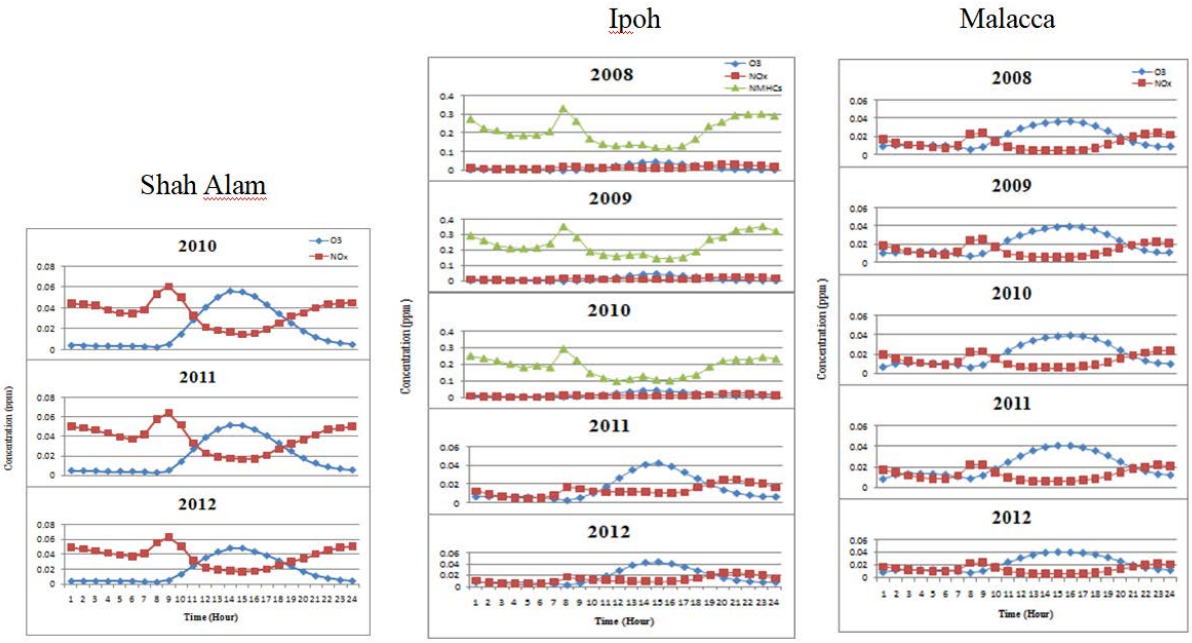

Figure 1. Diurnal fluctuation of O_3, NOx, and NMHC in three urbanized area.

In the present of sunlight, nitrogen dioxide (NO_2) and volatile organic compound (VOCs) involves in reaction of ozone. The ability of NOx and NMHC from local emissions such as vehicles and other anthropogenic activities must be considered to be among the contributing factor. Ozone is destroyed throughout the day and night but will formed only during daylight hours.

In hot, calm, and sunny day the concentration of ozone is high. Abdul-Wahabet. al. (2005) [1] pointed out that high temperature and high UVB will favour the formation of O_3 which is a photochemical species and this explained the afternoon peak of O_3. The formation of ozone is heavily influenced by sunlight and temperature. This study is accordance with the previous study conducted by [4].Before sunrise, the concentration of ozone reach a minimum value. Photochemical reactive become active along will increasing of temperature and solar radiation around 8.00. Around 15.00-16.00, the ozone concentration is reach the peak after begin to increase in the morning and appear as a weaker peak in the night time. This is caused by the transportation of ozone in the stratosphere vertically or accumulation of ozone due to the low boundary layer height at night [5].

Emission of NOx can be the one reason in the peak ozone concentration absorbed in numerous urban region or areas. Because catalyzes not only the ozone formation but also destruction, so, formation of ozone is relies on NOx concentration. This means, paradoxically, the higher production

of ozone concentration is from the lower ambient concentration of NOx. Sometimes it depends on VOCs and NOx proportion, UV light, Temperature, and humidity.NOx tend to slow down formation of ozone when ratio of VOC/NOx is low in the ambient air (NOx is plentiful relative to VOC). Formation of ozone called "VOC limited" when VOCs amount tend to limit the amount of ozone formation. The VOC/NOx proportion measured close to the ground would not characterize the ratio that prevails in the air over the ground where the most of the troposphere ozone iscreated.

3.3. Pearson correlation between Ozone and Meteorological Parameters

Pearson correlation is to determine the strength of a linear relationship between two variables and is meant by *r*. Table 2 show the Pearson correlation matrices of the variables in this selected urbanized area which are Shah Alam, Ipoh, and Malacca. The correlation coefficient between ozone and the various air pollutant and meteorological parameters were weak except for certain pollutant. It is show the correlation between different variables as well. The relationship between ozone, pollutant and meteorological parameter are being investigated by usingcorrelations.

For Shah Alam, a negative significant correlation between O_3–NO_2 which were evaluated at (r^2=-0.1162). The situation, then, can be explained by the high NO_2 emissions which enhanced O_3 buffering owing to the oxidation reaction of NO_2. The similar trends of correlation between O_3 and nitrogen compounds were observed by [6]. However, the pearson correlation matrix for Malacca show that O_3-H have a positive significant correlation which was measured at (r^2=0.2179).

In Ipoh, a negative significant correlation between O_3-WS, O_3-AT, and O_3-NO_2 were evaluated at (r^2=-0.4026), (r^2=0.3499), and (r^2=-0.1203) respectively. This illustrate that the photochemical reaction occur actively in the urban area atmosphere. The findings also indicate that humidity and wind speed also influences the O_3 and NO_2 concentrations by the washout and dilution effect. There also show the positive significant correlation between O_3-H which was evaluate at (r^2=-0.7819).

Table 2. Pearson correlation matrix of different variables for three urbanized areas.

Correlations								
Location	Parameter	WS	AT	H	SO_2	NO_2	O_3	PM_{10}
Shah Alam	WS	1	0.217	-0.19	-0.385*	-0.33	0.129	-0.138
	AT		1	-0.773**	0.335	0.393*	0.058	0.573**
	H			1	-0.381*	-0.514**	-0.137	-0.798**
	SO_2				1	0.376*	-0.052	0.478**
	NO_2					1	0.341*	0.686**
	O_3						1	0.206
	PM_{10}							1
Ipoh	WS	1	0.230	-0.645**	0.254	0.205	0.634**	0.355*
	AT		1	-0.694**	0.124	0.293	0.592**	0.572**
	H			1	-0.257	-0.278	-0.884**	-0.818**
	SO_2				1	0.232	0.218	0.270
	NO_2					1	0.347*	0.343*
	O_3						1	0.828**
	PM_{10}							1
Malacca	WS	1	-0.179	0.016	-0.19	-0.115	-0.038	0.019
	AT		1	-0.434**	0.460**	0.399*	0.301	0.295
	H			1	0.167	0.199	-0.467**	-0.081
	SO_2				1	.682**	-0.148	0.325
	NO_2					1	-0.106	0.403*
	O_3						1	0.492**
	PM_{10}							1

This correlation indicates that there are have some sources of the pollutant occur in this three areas since it is an urban area. This would lead to the existence of pollutant from various sources especially from motor vehicles movement. And the atmospheric temperature, humidity and wind speed also play important role in transporting this pollutant in certain condition to lead to surface ozone formation.

4. Conclusions

The changes in wind speed, wind direction, temperature, humidity, and solar radiation was accompanying by rapid changes of ozone and oxide of nitrogen formation involving the concentration of atmospheric trace gases. Emission of NOx are directly from vehicles and industrial, and depositions of trace gasses on surfaces are significant processes adjusting the ozone fixation close to the surface. Firstly, the levels and characteristics of ground level ozone concentration in all selected urbanized area were identified and explored by descriptive statistics and time series plot. The ozone concentrations in certain urban area are below the limit (0.1 ppm) as stipulated in Malaysian Ambient Air Quality Guidelines (MAAQG). For second objective, diurnal variation of ozoneconcentartion show almost the same pattern for all the studied areas. It indicate low concentration during early morning and late night and high concentration during day time whereas NOx and NMHC show opposite pattern to the ozone concentration. The decreasing concentration of the precursors is corresponding to the formation of ozone concentration. Pearson correlation shows that there is a positive and negative correlation between the ozone, pollutant source and also from meteorological parameter. This correlation indicates that there are have some sources of the pollutant occurred since it was an urban area. This would lead to the existence of pollutant from various sources especially from motor vehiclesmovement.

5. References

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Acknowledgments

The author would like to acknowedge Ministry of Higher Education Malaysia for the Fundamental Grant Scheme (FRGS 9003 00508) and Department of Environment Malaysia for the dataset.