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Effect of Monsoonal Period toward Night-time Ground Level Ozone in East Coast Malaysia

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Abstract. This study aims to identify the effect of monsoonal period toward nighttime ground level ozone in East Coast Malaysia depending on different land use area which is industrial and urban areas. The concentration of O_3, NO, NO_2 temperature (T), relative humidity (RH) and wind speed (WS) were used and collected from Air Quality Division of the Department of Environment, Malaysia. The data proceeded in descriptive analysis and statistical analysis. Temperature, relative humidity and wind speed parameters (symbol of East Coast Monsoonal period), was compared with O_3, NO and NO_2 concentration with Pearson correlation analysis. During nighttime, O_3 concentration continuously decreasing starting at 7 p.m. promotes by chemical removal and other removal processes. The highest nighttime O_3 concentration was recorded 65 ppb (Kemaman) with the lower nighttime ozone achieved zero value. Meanwhile, nighttime O_3 concentration in Kota Baharu (nighttime) was recorded lower with maximum (612 ppb) and mean (9.15±8.60 ppb) compared to Kemaman. The temperature and relative humidity correlation with O_3 concentration in both locations shown different correlation as Kemaman -0.149 and 0.212 while Kota Baharu exhibited 0.137 and -0.159. Meanwhile, wind speed has a positive correlation in both locations as Kemaman is 0.388 and Kota Baharu is 0.462 which indicates wind was a factor that induces ozone formation as ozone was transported to the monitoring area. Therefore, NO, NO_2, T, RH and WS was not the only factor influences ozone depletion during nighttime as the correlation display was lower.

1. Introduction

Environmental problems are getting severe but less concern is given due to the massive globalization. Air pollution has been a substantial challenge among the various environmental problems that affect human health and loss of welfare from environmental causes in Asian countries [1]. As the second pollutant, 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 the ozone layer. However, it gives a bad effect on human health or living organisms found in the ambient air including in Malaysia. Numerous studies stated ground level ozone during daytime gives a negative impact either to humans [2] or vegetation [3,4] as well as the environment. The effect of ground level ozone can be contributed by topographic conditions, seasonal variation and geographical location [5].

Majority of the existance of ground level ozone are induced by the emissions of nitrogen oxides (NO_x) and volatile organic compound (VOC). Due to the existing of sunlight, NO_2 undergoes photolysis to produce free oxygen atom (O) where then will react with the oxygen molecule (O_2) to form ozone (O_3) [6]. In the morning, O_3 concentration was generally started to produced and accumulated to reach its peak during the late afternoon. High O_3 concentration only detected during daytime (noon or early afternoon) as stated in Ghosh et al. [7], then continue gradually decrease during the evening. However, during nighttime O_3 concentration constantly decreasing as there are no photochemical reactions occur and as addition of further destruction due to NO titration and deposition process [7]. However, Awang et al. [8] reported that the existing ozone removal mechanism during nighttime could be higher than usual due to the inefficient removal mechanism.

Furthermore, a lot of studies stated that O_3 concentration can be dependable on meteorology [9,10,11]. Chen et al. [12] stated that the temperature, was the key influencing ozone concentration while supported by relative humidity, wind speed. Tong et al. [13] proved that high humidity has negatively correlated with O_3 concentration while temperature is shown positive correlation with O_3, as ozone production. The temperature was a symbolic condition of sunlight condition while relative humidity was translated to be rainfall condition. However, MDD [14] stated that Malaysia experiencing three different influence of climate change, which is wind pattern, rainfall and temperature. All of this component was referred to the monsoon period in Malaysia. There are four monsoon seasons changes in Malaysia which are northeast monsoon, southwest monsoon, first and second intermonsoon [15]. East Coast Monsoon occurred between November to March.

According to Jamaluddin et al. [16], daily average rainfall in East Coast region was not influence the nocturnal ozone concentration in Malaysia. However, the highest rainfall and strong wind speed throughout the East Coast Monsoon period translates to low ozone production. Due to different distribution of temperature and wind speed on Malaysia according to the seasonal period, the nighttime ground level ozone needs to be studied thoroughly and analyzed by seasonal condition (East Coast Monsoon). Therefore, this study aims to have a better understanding of nighttime ozone variation and its trends during the East Coast Monsoonal period.

2. Materials and Methods

2.1 Study Area

This study focusing on two location area which is Kemaman, Terengganu and Kota Baharu, Kelantan. This location stated in The East Coast, Peninsular Malaysia with a different types of land use. Kemaman, Terengganu is known as the industrial area which is known for the discovery of a petroleum site near its town Kerteh in the early 1980s. With the population of 166,750 in 2010, this district is relatively underdeveloped, except for a few places along the coastline, in which steel and petrochemical plants are located [17]. According to Ismail et al. [18], Kemaman has two major industrial sites (i.e., Kerteh Petrochemical and Gebeng Industrial Area). The annual rainfall in Kemaman is 3000 mm on average, with a standard temperature of 26.5 °C and relative humidity at approximately 81 % year-round [14].

Meanwhile, Kota Baharu is located in Kelantan, which is the urban area in East Malaysia. Kota Bharu is Kelantan's capital city at the river mouth of Kelantan. It has an estimated population of 314,964 (2010 census) and covers an area of 394 km^2 [19]. The major land use in Kota Bharu is for agriculture, with one industrial park at Pengkalan Chepa [20]. Climatically, Kota Bharu experiences a tropical rainforest climate distinguished by high temperature and relative humidity with heavy seasonal rains during northeast monsoon (November to January) [17]. According to MMD [14], Kota Baharu recorded the highest daily average in wind speed with 7.1 m/s in December 2017.

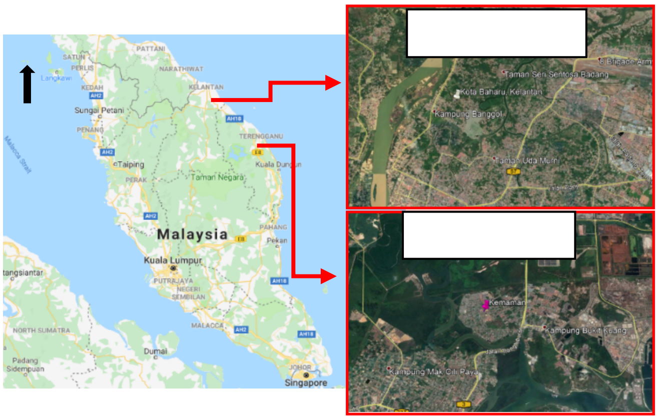

Figure 1. The location of study areas through satellite image of Kota Baharu, Kelantan and Kemaman, Terengganu (Google Earth Map)

2.2 Data Acquisition

Hourly data of O_3, NO, NO_2 concentration for January – March and October- December for four (4) selected years (2008-2011) was obtained from the Air Quality Division of the Department of Environment, Ministry of Natural Resources and Environment of Malaysia. This hourly data of ozone was monitored using the Model 400E UV Absorption Ozone Analyzer [21]. The analyzer utilizing the Beer-Lambert Law, which based on the internal electronic resonance of O_3 molecules with the absorption of 254 nm UV light in measuring low ranges of O_3 concentration in ambient air [10, 22]. Meanwhile, NO_2 and NO concentration was monitored using the Model 200A NO/NO_2/NO_x Analyzer [10]. Mohammed et al. [22] stated that the quality control process and the quality assurance procedures were measured based on the obtained secondary data. Therefore, all the procedures must have standardized by internationally recognized environmental agencies such as the United States Environmental Protection Agency [23].

2.3 Data Analysis

This study focuses on nighttime ground level ozone which lies between 7 p.m. to 7 a.m. [22]. The data were analyzed as descriptive analysis and statistical analysis. The method of data analysis that was used is descriptive analysis and diurnal plot. Meanwhile, Pearson correlation with the aid of SPSS software to determine the relationship between ozone and its precursor with meteorological elements as represented condition while East Coast Monsoon in Malaysia.

Correlation analysis was used to calculate the association between two continuous variables. The output variable was called dependent variable whereas the risk factor was called independent variables. For correlation analysis, the examined sample correlation coefficient was the Pearson Product Moment correlation coefficient and the symbol for correlation coefficient was r. The range of correlation coefficient was between -1 and +1 and it calculated the management and strength of the association between the two variables.

3.0 Results and Discussion

3.1 Descriptive Statistical of Nighttime Ozone with Its Precursor and Meteorological Factors

Descriptive analysis referred to the systematic observation and description of the characteristics or properties of objects or events. In this study, Table 1 shows the descriptive analysis of nighttime ozone concentration with precursor in Kemaman and Kota Baharu for 2008-2011 during East Coast Monsoon. Results in Table 1 showed that the nighttime O_3 concentration in Kemaman, Terengganu throughout four (4) monitoring year (2008 - 2011) was generally low, with the mean values of 17.15±11.46 ppb. The highest maximum nighttime O_3 concentration was 65 ppb which did not exceed the Recommended Malaysia Air Quality Guidelines (RMAQG) of 100 ppb. Meanwhile, Kota Baharu showed a similar condition in which the mean value stated 9.15±8.60 ppb. Over the period investigated, the maximum nighttime is 61 ppb. The minimum nighttime O_3 concentrations in Kemaman and Kota Baharu achieved zero values. The O_3 concentration had been reduced at nights due to the nighttime removal chemistry. There is no formation of O_3 and loss through NO titration in nighttime and significantly reduces the O_3 concentrations until achieving zero value [8,24,25].

Table 1. Descriptive statistical of nighttime ozone concentration with precursor in Kemaman and Kota Baharu for 2008-2011 during east coast monsoon

Variables	Kemaman, Terengganu				Kota Baharu, Kelantan			
	Min	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**
Ozone, O_3 (ppb)	0	65.00	17.15	11.46	0	61.00	9.16	8.60
Nitrogen Dioxide, NO_2 (ppb)	0	23.00	2.40	2.40	0	62.00	9.92	6.29
Nitric Oxide, NO (ppb)	0	60.00	0.84	3.30	0	137.00	5.37	8.93
Temperature, T (^{o}c)	20.00	33.00	23.60	1.88	19.70	30.60	24.96	1.68
Humidity, RH (%)	20.00	100.00	80.75	11.58	55.00	100.00	87.49	8.03
Wind Speed, WS (m/s)	1.00	13.50	3.19	1.54	0.50	17.20	3.51	2.99

Meanwhile, NO and NO_2 concentrations showed a similar condition as directly proportional to each other in both locations. The mean of nighttime NO and NO_2 concentrations (NO: 0.84±3.30 ppb, NO_2: 2.40±2.40 ppb,) in Kemaman stated lower than the mean of nighttime NO and NO_2 concentration (NO: 5.37±8.93 ppb, NO2: 9.92±6.29 ppb,) in Kota Baharu. The maximum NO and NO_2 concentrations recorded in Kemaman were 60.00 ppb and 23.00 ppb and Kota Baharu showed higher maximum NO and NO_2 concentration with 137.00 ppb and 62.00 ppb, respectively; but these values are well below the RMAQG limit with 170 ppb (NO_2). The NO_2 and NO concentration were higher in Kota Baharu (urban) due to high emission of vehicle to produce NOx gases more than Kemaman (industrial). According to Awang and Ramli [24] the depletion of O_3 during nighttime was due to NO titration and deposition process. NO and NO_2 concentration was the major chemical used in NO titration of nighttime O_3 concentration and NO_2 is the significant sink agent of O_3 [6]. The minimum of nighttime NO and NO_2 concentration also achieved zero value.

3.2 Diurnal Plot in Kota Baharu, Kelantan and Kemaman, Terengganu

Diurnal plot was produced to monitor the pattern of ozone and its precursor throughout the average concentration of hourly in four (4) selected years (2008-2011) based on selected months from the monsoonal period (October-March). Meanwhile, diurnal variations of O_3 concentration was made to elaborate the pattern and it was controlled by a few processes which is photochemistry, physical and chemical removal, deposition and transport rate [10, 26, 27]. However, this study focuses on the monsoonal period which happens in October until March, as representing the East Coast Monsoon in Malaysia.

Figure 2 showed the diurnal variation of two selected locations in East Malaysia with different backgrounds (i.e. urban and industrial) throughout 4 years (2008-2011). Duration of 7 p.m.-7 a.m. was recorded as the nighttime, and there no O_3 production in nighttime due to the absence of sunlight. Both of the locations undergo the same pattern of O_3 concentration which the O_3 concentration starts increased at 8 a.m. and decreased obviously after sunset (7 a.m.). O_3 concentration was stated low and constant during nighttime. This finding reported to has a similar conditions with Ghost et al. (2013) [7] in Kolkata. However, O_3 concentration in Kemaman displayed higher than Kota Baharu either during daytime or nighttime.

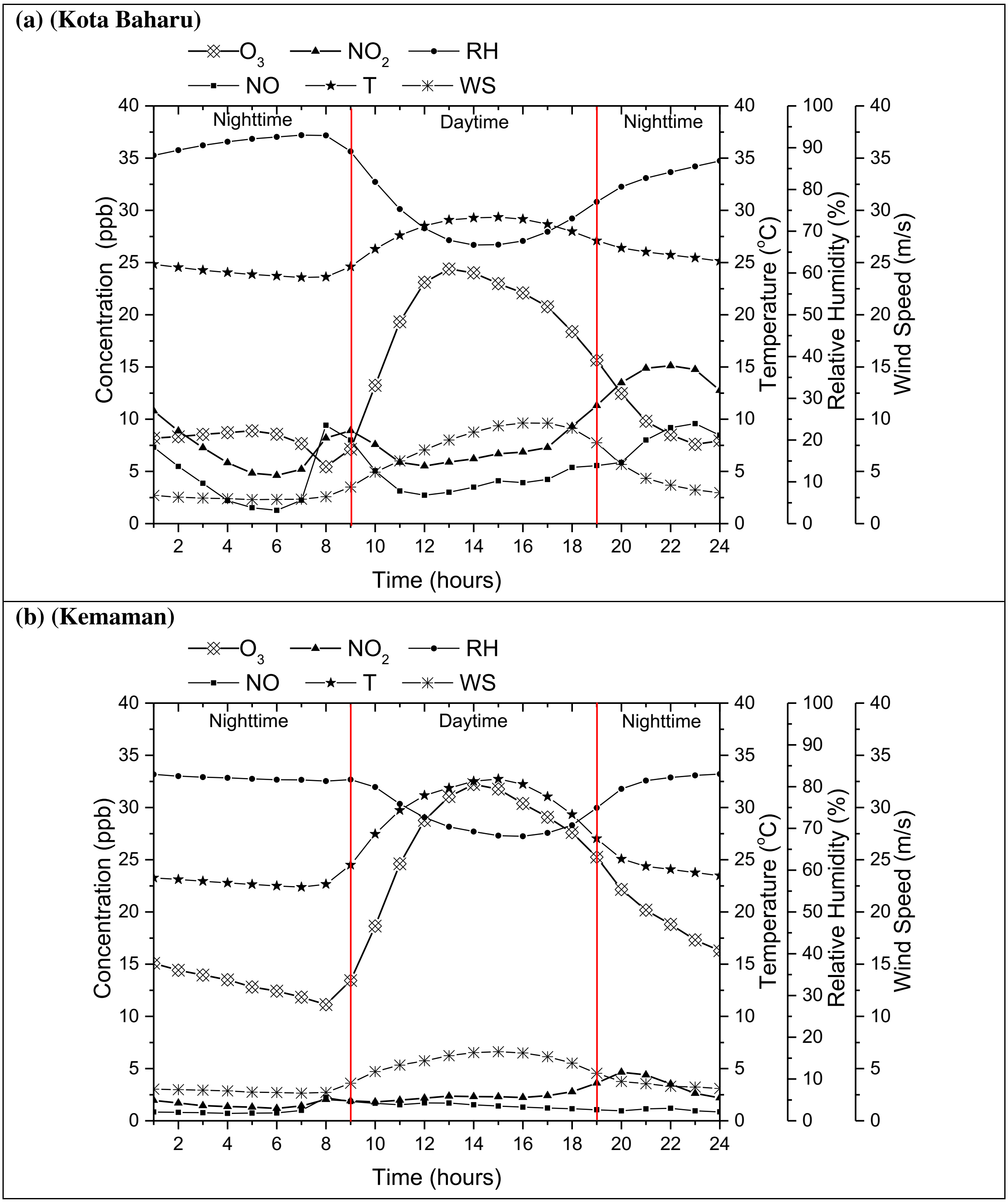

Figure 2. Diurnal variation of ozone, nitric oxide, nitrogen dioxide, temperature, relative humidity and wind speed at (a) Kota Baharu, Kelantan and (b) Kemaman, Terengganu.

NO and NO_2 concentrations showed in diurnal variation was slightly different as the observed NO and NO_2 concentration in Kota Baharu displayed higher during nighttime compared to Kemaman. NO and NO_2 concentration in Kota Baharu increased significantly after 8 p.m. and continue to decrease back afternoon, while NO and NO_2 concentration in Kemaman remain low and constant throughout the day.

The diurnal pattern in Kota Baharu exhibited two peaks concentration for NO and NO_2 concentrations. This finding was similar to Awang and Ramli, [24] which the diurnal trends in Kota Baharu exhibited two peaks in concentration which stated at 8 a.m. and 10 p.m. Furthermore, Ghazali et al. [10] also elaborated the same NO_2 pattern in Malaysia which two peak concentration occurs in morning (9 a.m.-10 a.m.) and evening (8 p.m. -10 p.m.). During nighttime, NO_2 for both stations showed higher than NO concentration. The higher NO_2 in nighttime was due to ozone deposition and created NO_2 concentration. There was one reaction which is O_3 reacts with NO to produce NO_2 and O_2, which also happens in the nighttime. This reaction is the cause that the high concentration of NO_2 [6].

The variations meteorological factor such as temperature (T) and relative humidity (RH) was the symbolic representative of the monsoonal condition in this study. Meteorological factors also played an important role in affecting the concentration of O_3. Therefore, this study averages the temperature and relative humidity in the selected month and the general trends for relative humidity show the high percentage and it achieved 100 %. Meanwhile, the temperature was in the moderate condition as the average temperature was 24.96±1.68 °C (Kota Baharu) and 23.60±1.88 °C (Kemaman). The temperature was decreased in the nighttime after sunset. This was due to the absence of sunlight during nighttime.

3.3 Correlation Analysis between Nighttime Ozone with Its Precursor and Meteorological Factors

Table 2 shows the correlation of ozone with its precursor and meteorological factor. The correlations of O_3 concentration with NO and NO_2 concentration for both location was a negative correlation (Kemaman: -0.103 and -0.163; Kota Baharu: -0.161 and -0.324). Meanwhile, the correlation of O3 concentration with the temperature at Kemaman was a negative correlation (-0.149) and Kota Baharu exhibited positive correlation (0.137). According to Punithavathy et al. [28], the temperature can significantly affect the O_3 concentration with high positive correlation but this study shows the different results as Kemaman exhibited lower negative correlation.

Table 2 Correlation between O_3 Concentration with its precursor and meteorological parameter in Kemaman and Kota Baharu

Station	Parameter	Nighttime (7 p.m. – 7 a.m.)					
		O_3	NO	NO_2	T	RH	WS
Kemaman, Terengganu	O_3 (ppb)	1	-0.103	-0.163	-0.149	0.212	0.388
	NO (ppb)		1	0.437	0.195	0.089	-0.168
	NO_2 (ppb)			1	-0.030	-0.004	-0.114
	T (°C)				1	0.370	0.146
	RH (%)					1	-0.067
	WS (m/s)						1
Kota Baharu, Kelantan	O_3 (ppb)	1	-0.161	-0.324	0.137	-0.159	0.462
	NO (ppb)		1	0.516	0.257	-0.029	-0.095
	NO_2 (ppb)			1	0.100	0.014	-0.169
	T (°C)				1	0.101	0.324
	RH (%)					1	-0.119
	WS (m/s)						1

Furthermore, the correlation of O_3 concentration with relative humidity shown the vice versa of temperature. In Kemaman, relative humidity had a positive correlation (0.212) while, the negative correlation shown at Kota Baharu (-0.159). Although Tong et al. [13] and Hashim et al. [29], stated that a strong negative correlation of O_3 concentration and relative humidity in their study. Our findings in Kemaman displays the positive correlation which explained that humidity was not one of the factors that helps for ozone destruction in nighttime. Moreover, wind speed has positive correlation to in both locations as Kemaman is 0.388 and Kota Baharu is 0.462 which indicates wind was a factor that induces ozone formation as ozone was transported to the monitoring area.

Conclusion

Northeast monsoon was prominent in the Eastern Coastal area in Malaysia due to high rainfall intensity and also promote wet deposition of ozone. Therefore, this study aims to identify the effect of monsoonal period toward nighttime ground level ozone on East Coast Malaysia depending on different land use area which is an industrial and urban area. Kemaman and Kota Baharu showed low concentration of O_3 with a mean value 17.15±11.46 ppb and 9.15±8.60 ppb. Meanwhile, the minimum value for ozone in both locations achieved zero value. Zero concentration showed that O_3 concentration was completely depleted in nighttime. The diurnal cycle of O_3, NO, NO_2, T, RH and WS was similar in both locations. However, there was two peak concentration of NO and NO_2 concentration was detected in Kota Baharu. The seasonal dispersal of O_3 concentration was influenced by the seasonal wind as the highest correlation stated for both locations. However, the temperature and relative humidity correlation with ozone were different for both locations. Kemaman had a negative correlation for temperature and ozone, while a positive correlation for relative humidity. Thus, Kota Baharu showed positive correlation for temperature and negative correlation for relative humidity. This finding showed that NO, NO_2, T, RH and WS was not the only factor influences ozone depletion during nighttime as the correlation display was lower.

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