FLUCTUATIONAL ANALYSIS OF NIGHTTIME GROUND LEVEL OZONE CONCENTRATION DUE TO VARIATIONS IN HOURLY RELATIVE HUMIDITY

by

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DECLARATIONS

I declare that this thesis entitled Fluctuational Analysis of Nighttime Ground Level Ozone Concentration Due to Variations in Hourly Relative Humidity is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Fluctuational Analysis of Nighttime Ground Level Ozone (O_3) Concentration Due To Variations In Hourly Relative Humidity

ABSTRACT

Ground level ozone (O_3) is not emitted directly into the atmosphere. It results from photochemical reactions between precursors and influenced by meteorological factors such as relative humidity and temperature. Therefore, this study aimed at investigating the influence of relative humidity and temperature in the fluctuation and transformation of $O_{3.}$ Hourly monitoring data of $O_{3,}$ relative humidity and temperature in Shah Alam from 2006 to 2010 were acquired from the Department of Environment (DoE) which then was extract according for nighttime O_3 data. Monitoring for three days has been carried out in Shah Alam for primary data collection. Both primary and secondary data were analyzed using descriptive statistics, box and whisker plot, time series and diurnal plot as well as multiple linear regressions (MLR). The result showed that minimum O_3 concentration was 0 ppb during 2006 to 2010 year. Meanwhile, the maximum O_3 concentration was 91 ppb in 2009.The diurnal pattern of O_3 concentration has higher amount during daytime rather than nighttime. This variation between day and night generally coincides influenced by relative humidity and temperature. MLR analysis was use for modeling the O_3 concentration. MLR models showed that variations in ozone concentrations were attributed to variation of few meteorological parameters with $R^2 \approx 0.299$. As conclusion, lower humidity increased the amount of ground level ozone concentration and increasing amount of ground level ozone concentration is influence by the higher temperature of its surrounding.

Analisis Turun Naik Kepekatan Ozon Waktu Malam Berdasarkan Variasi Kelembapan Udara

ABSTRAK

Ozon paras bawah tanah (O_3) tidak dibebaskan secara langsung ke atmosfera. Ozon dihasilkan daripada tindak balas fotokimia antara prapenandanya dan dipengaruhi oleh faktor-faktor meteorologi seperti kelembapan udara relatif dan suhu. Oleh itu, kajian ini bertujuan untuk mengkaji pengaruh kelembapan udara relatif dan suhu ke atas turun naik kepekatan O_3 waktu malam. Data pemantauan pada setiap jam kepekatan O_3, kelembapan udara relatif dan suhu di Shah Alam dari 2006 hingga 2010 diperoleh dari Jabatan Alam Sekitar (DoE) yang kemudiannya diasingkan berdasarkan data O_3 pada waktu malam. Pemantauan selama tiga hari telah dijalankan di Shah Alam untuk mengumpul data primer. Data primer dan sekunder dianalisis menggunakan statistik deskriptif, kotak dan plot kumis, siri masa dan plot harian serta analisis regresi linear berganda (MLR). Keputusan menunjukkan bahawa kepekatan minimum O_3 adalah 0 ppb sepanjang tahun 2006 hingga 2010. Sementara itu, kepekatan O_3 maksimum adalah 91 ppb pada tahun 2009. Corak harian O_3 kepekatan mempunyai jumlah yang lebih tinggi pada siang hari daripada waktu malam. Perubahan ini antara siang dan malam umumnya bertepatan dipengaruhi oleh kelembapan relatif dan suhu. Analisis MLR digunakan untuk memodelkan kepekatan O_3. Sebagai kesimpulan, kelembapan yang lebih rendah telah meningkatkan jumlah kepekatan ozon paras tanah dan peningkatan jumlah kepekatan ozon paras tanah yang dipengaruhi oleh suhu yang lebih tinggi di persekitarannya.

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LIST OF ABBREVIATIONS

AQI	Air Quality Index
a.m.	Ante meridiem
DoE	Department of Environment, Malaysia
DW	Durbin Watson
GSS	Gas sensitive semiconductors
hv	Radiant energy
MAAQG	Malaysia Ambient Air Quality Guidelines
MLR	Multiple Linear Regression
NAAQS	National Ambient Air Quality Standards
O	Oxygen atom
O_2	Oxygen molecule
O_3	Ozone
p.m.	Post meridiem
ppb	Parts per billion
R^2	Coefficient of determination
RH	Relative humidity
SPSS	Statistical Package for the Social Science
T	Temperature
USEPA	The United State Environmental Protection Agency
UV	Ultraviolet
VIF	Variance Inflations Factors

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Earth is roofed by a layer of gas referred atmospheric. It extends to approximately 160,000 km above the surface area. The atmosphere roughly contains of 78% nitrogen, 21 % oxygen and traces amount of other gases for example methane, ozone and carbon dioxide. Relative humidity, wind speed and temperature are examples of meteorological factors. Meteorological factors and changes within concentration of traces are closely connected (Lyubovtseva *et al*., 2005).

There are numerous methods of categorizing the distinctive part air. Most frequent categorizing is primarily between variants of temperature and vertical distribution in the air. According to National Institute of Water and Atmospheric (2016) atmospheric layer were divided into four classifications. Troposphere located closely to the earth, continued with stratosphere that contain ozone layer, next is mesosphere knows as coldest layer and lastly is thermosphere where increase of temperature occur. The size and limit of every layer don't seem to be same at some point of the globe however vary in several time and locations.

Air pollution is continuous and widespread environmental issues that result in human wellbeing implication and financial expenses (Ghorani-Azam *et al*.,2016). Stated by World Health Organization (2017), accumulation of any agents emitted from outdoor or indoor environment that may change the common characteristics of the atmosphere referred as air pollution. Air pollutants can be characterized into primary and secondary pollutants. Pollutants such as sulphur dioxide that are discharged directly from factories slag from volcanic emission or monoxide gas from vehicles known as primary pollutants (Carlos, 2018). Whereas, pollutants that are not discharged directly from point sources is known as secondary pollutants (Sharma *et al.*, 2013). Ground level ozone is one of the significant instances examples of secondary pollutants (Vallero, 2014). Ozone is colorless gas with formula O_3 which is the minor constituent of the atmosphere (Smit, 2015).

Troposphere and stratosphere are the two layers of the atmosphere wherever ozone can be discovered, troposphere is the nearest to Earth's surface, at troposphere ground level ozone good or bad ozone can harm trees, crop and other vegetation (Pielke, 2019). This ground level ozone is an air pollutant that's destructive to human respiratory system. It is a primary ingredient of urban smog (Pénard-Morand & Maesano, 2004). The good ozone layer situated from 9.7 to 48.2 km, act as protection on Earth layer from the harmful ultraviolet of sun (Palanna, 2009). Among the foremost significant factor that can influence on variations of ozone concentration are relative humidity and temperature; metrological factors (Zhang & Jiang, 2018).

1.2 Problem Statement

Increase or decrease of ozone concentration turns into a serious health quality issue. According to United State Environmental Protection Agency (2017), high concentration of ozone decreased human wellbeing that impact from anthropogenic sources, it altered the amount of ozone concentration. Throughout daytime, increasing amount of vehicles on the roads can contribute to higher ozone precursors therefore generate additional ozone concentration (Zhang & Batterman, 2013). During nighttime, the amount of vehicles was lesser; therefore the ozone precursors were limited. Furthermore, other meteorological factor such as relative humidity, temperature, wind speed and direction that additionally have an effect on concentration of ground level ozone (Han *et al.*, 2011). Concerning to case study in Brazil, it declared that increasing of relative humidity caused the reduction of ozone concentration (Czajkpwski, 2015). Generally, ozone concentration was low throughout nighttime because of absence of photochemical reactions. In line with previous study, increasing of nighttime NO concentration exaggerated reduction of nighttime ozone concentrations (Awang & Ramli, 2017). Based on monitoring of air quality at University of Warmia and Mazury it concluded that depletion of ozone was higher because of absence of photochemical reaction at nighttime (Warmiński & Bęś, 2018). Reduction of ozone is vital to reduce the buildup of ozone within the air and directly reduce quantity of pollutants concentration in the atmosphere. Eventhough it have be prove that formation of ozone which included the presence of sunlight and NO_2 which undergoes photochemical reactions to produce free oxygen atom (O_2) which later reacts with oxygen molecules (O_2) (Duenas *et al.*, 2004 ; Azmi *et al.*, 2010). However this study only focusing on nighttime, thus sunlight was excluded from this analysis. Due to lack of information O_3 studies in Malaysia, the aims of this study to investigate the fluctuational behaviour of O_3 during nighttime that influenced by relative humidiy and temperature.

1.3 Objectives

i. To determine the concentration of ground-level ozone, relative humidity and temperature during nighttime.

ii. To investigate the influence of relative humidity and temperature towards ground level ozone concentrations sinking reactions during nighttime.

iii. To establish the relationship between ground-level ozone concentration, relative humidity and temperature during nighttime.

1.4 Scope of Study

Shah Alam, Selangor is the location that has been chosen to conduct air monitoring. Ground level ozone concentration during nighttime was one of the concerns in this research. Due to the variations in hourly humidity, it fluctuate ground level ozone concentration behavior. This study is to determine and investigate the relative humidity and temperature which act as meteorological conditions that influenced the ozone concentration. Analysis method in this research was based on primary data from air quality monitoring and secondary data from year 2006 to 2010 that acquired from DoE using specific equipment which are Model 400E UV Absorption Ozone Analyzer, Portable Humidity Temperature Meter Model and Met One 083D instruments.

1.5 Significance of Study

This study is to enhance better understanding on concentration of O_3 at nighttime that was influenced by relative humidity and temperature. This research was is to reduce the adverse effect of ozone particular on human health. Example, avoid spending too much time outdoors and aware about aware about Air Quality Index (AQI) in that area. It has been estimated around 5000 premature deaths per year that show significant health effects of ground level ozone concentrations on population in United States (Holm, Balmes, & Roy, 2018). This study is important for our community, government, public or private sector to get information concerning the effect on their health.

CHAPTER 2

LITERATURE REVIEW

2.1 Ozone

In the troposphere, ozone naturally exists in abundant (Rowland, 2006). About 1.6 times, ozone is heavier than air (Spellman, 2016). Secondary pollutant is referring to ozone pollutants; anthropogenic precursors allowed photochemical reaction (Cecchi, D'Amato, & Maesano, 2013). The most vital precursors are NOx and VOCs. Formation of ozone due to viability of daylight is referred to as secondary pollutants (Madronich *et al*., 2015). Ozone in stratosphere was tolerable however it's unsafe once ozone in troposphere was accumulated.

2.2 Formation of Ozone

Through method of photochemical reactions in surrounding air, ground level ozone was formed (Seinfeld & Pandis, 2006). Temperature, relative humidity, NO_X emission and concentration of CO are meteorological factors that a very significant role in photochemical reaction. With the presence of daylight including discharged from human activities for example VOCs and NO_X photochemical reactions can occurred and ozone was formed. With the aids of sunlight and NO_2, O_3 was formed when oxygen atom react with oxygen molecule.

Reactions between O_3, NO_2 and NO concentration clearly show by reactions below:

$$O_2 + O + M \longrightarrow O_3 + M \quad (2.1)$$

$$NO_2 + hv\ (\lambda < 400\ nm) \longrightarrow NO + O \quad (2.2)$$

$$NO + O_3 \longrightarrow NO_2 + O_2 \quad (2.3)$$

Where:

M is a third element such as N_2 or O_2.

Hv is solar radiation

During daytime as stated at Equation (2.3) formation of NO_2 was continued, these formation was used during nighttime for photochemical reaction of O_3 stated at equation (2.4). Based on equation (2.5) At nighttime, wherever O_3 and NO_2 react, O_2 and NO_2 were formed. Formation of N_2O_5 was not stable and it reversed the reactions, occurred by reactions of O_2 and NO_3 was formed but it is unstable and it reversible to form O_2 and NO_3 as shows by reactions below:

$$O_3 + NO_2 \longrightarrow O_2 + NO_3 \quad (2.4)$$

$$O_2 + NO_3 \rightleftarrows N_2O_5 \quad (2.5)$$

Based on previous study, stated that decreased of O_3 concentration during nighttime in Kota Bharu due to non-appearance of photochemical reactions, and the increasing of O_3 formation was influenced by its precursor NO_x (Awang & Ramli, 2017).

2.3 Ozone precursors

Precursor is the formation of another compound through chemical reaction process. Nitrogen oxide (NOx) and volatile organic compound (VOCs) are emissions of from sources that act as O_3 precursors (Torres-Jardón *et al.*, 2009). NO_x is emitted from burning fuels in industries or automobile into air whereas VOCs emitted from vehicles and industrial sources. Emission of ozone precursors will influence the ground level ozone concentration (Dagiliūtė & Uždanavičiūtė, 2010). Ensuing, higher formation of ground level ozone caused negative impacts to plants and animals.

2.3.1 Nitrogen Oxide (NO_x)

Nitrogen oxides make up nitrogen and oxygen and it additionally combination between of NO and NO_2 (Lindberg & Rydgren, 1998). NO and NO_2 was the most risky and usual nitrogen oxides (Sullivan *et al*., 2013). Example of nitrogen oxides, emission that discharge from burning coal, diesel fuel, vehicle fumes and natural gas, particularly from electric power plants. According to previous study, it expressed that exposure to NO_x pollutants emitted from natural or anthropogenic sources that effect the functioning of lung and can caused respiratory infliction. One of recommendation concerning to NO_x pollutants issue at toll plaza s in Malaysia was observed, an individual exposure for 8 hours shifts will increased the negative impact of air pollution (Ekeu-wei,Azuma, & Ogunmuyiwa , 2018). Nitrogen oxide discharge naturally and caused nitrogen and oxygen to react to form nitric acid. Nitric acid quickly reacts to oxygen molecule to form nitrogen dioxide. Chemical smog formed once NO_x react with sunlight or others (Donaldson & Wren, 2015).

2.3.2 Volatile Compound (VOCs)

Any compound of carbon excluding carbon dioxide, carbon monoxide carbonic acid, carbonates and ammonium carbonate which takes an interest in atmospheric are outlined as volatile organic compound, according to United States Environmetal Protection Agency (2017). VOCs are emitted as gases from specific molecule (Sethi, Nanda, & Chakraborty, 2013). VOCs embrace a spread of hazardous that may have effect to human wellbeing. Primary emission sources such automobiles were produce VOCs (Ghorani-Azam *et al.*, 2016). Adverse effects of VOCs were bronchial asthma and respiratory system.

2.4 Effect of Ozone on Human Wellbeing

There are a ton of negative effects that structure in regards to higher in O_3 concentration. High exposure of O_3 can prompt infliction of respiratory. This accidentally expanded amount of mortality. Inhalation of O_3 pollutants; caused shorten of human living period. Based on previous study in U.S, strong evidence regarding the impact of ozone resulted in death. At the point when more elevated levels of ozone, it expanded the danger of premature death that has been confirmed by newer analysis even when different pollutants exist (Zanobetti & Schwartz, 2008). Breathing in ozone, influenced the heart and affect the lungs conditions.

2.5 Meteorological Parameters That Influence O_3 variations

Fluctuation of ozone concentration is influence by meteorological conditions. Instances of meteorological conditions in concern in this study are temperature, relative humidity and wind speed. Most recent studies showed that meteorological impact have turned out to be one of the factors that increased the ozone concentration. Ozone concentration and temperature give positive correlation based on research on Heat Wave in France, however the effect of ozone pollution was assessed on its circumstances according to it ozone concentration (Lacour *et al.*, 2009)

2.5.1 Relative Humidity

Measure of water that present within air contrasted to amount that air potential to hold at that temperature knows as relative humidity. Higher measure of temperature corresponds to lower relative humidity, corresponded to higher solar radiation and higher ozone concentration (Quansah, Amekudzi, & Preko, 2012). As indicated by Environmental Protection Agency (2017) concentration reach higher amid colder months. The analysis confirms that ozone concentration is usually increasing with increasing of temperature and ozone concentration decreased with increasing of relative humidity. For low ozone concentrations the device response increases with increasing humidity. Based on study in Poland, it expressed that ozone concentration not correlate with relative humidity (Warmiński, & Bęś, 2018). Regarding to analysis has been done in urban zone situated in Cairo, it concluded that there was positive correlation among ozone and relative humidty amid summer season (Khoder, 2009). Ozone fluctuations influenced by meteorological factor such as wind and relative humidity. Those factors played significant roles in the formation and depletion of Ozone during daytime and nighttime (Ghazali *et al*., 2010).

2.5.2 Temperature

Relationship between temperature and ozone was positively correlated. It demonstrated, increasing of encircling temperature lead to increase the concentration of ozone. Based on previous study in Belgium, it concludes that the result of increasing of ozone level during summer, surplus of mortality amount. Temperature was strongly correlated with ozone (García-Herrera *et al*., 2010). Regarding to previous analysis in South China it stated that, ozone sensitivity clearly affected by temperature as displayed within the correlation maps in 2010, was the high correlation between formation of ozone and temperature (Lee *et al*., 2014). When temperature increased, the ozone production also increased, which it showed strong positive correlation between those variables (Quansah, Amekudzi, & Preko, 2012). The ozone production was affected by temperature directly through the speeding up of chemical reaction within precursor's (Coates *et al*., 2016).

2.6 Monsoonal Variations in Malaysia

Weather of Malaysia throughout the year was hot and humid due to its location which closed to the equator. The nature of Malaysia's climate and weather implies that it encounters a monsoon season as it depending on location. Based on Malaysian Meteorological Department (2017), there were two monsoon experienced in Malaysia which is the south-west and north-east monsoon. From May to September; Malaysia experienced the south-west monsoon while the north-east monsoon was experienced in November to March. In any case exterior the monsoon seasons, the weather was exceptionally pleasant and characterized by sunny during daytime while cooler during nighttime. West coast of peninsular Malaysia do not force much noteworthy of monsoon seasons. Meanwhile, there was significant influenced on east coast of peninsular Malaysia. Monsoonal effect such as temperature, rainfall, wind and others played significant result in air pollutants quality (Mohtar *et al.*, 2018).

2.7 Multivariate Analysis

The fluctuational analysis of O_3 concentration that influenced by relative humidity and temperature was clarified using diverse sort of analysis investigation**.** Multiple Linear Regressions (MLR) was used for data analysis investigation in this research. An MLR model was built from data collection between variables; dependent and independent variables. The assumptions model of multiple linear regressions was tested using Variance Inflation Factor (VIF) and Durbin –Watson.

CHAPTER 3

MATERIALS AND METHOD

3.1 Study area

This study was done between 24th July to 26th July 2019 located at Shah Alam, Selangor with coordinates 3°4′20″N 101°31′00″E. Figure 3.1 shows map of Shah Alam in Peninsular Malaysia, according to World Population Review (2019) stated that Shah Alam having about 481,654 inhabitants. The rapid transformation of Shah Alam into a wide urban has contributed too many of the environmental issues, specifically air pollution. This research was studied the influenced of temperature and relative humidity towards O_3 concentration during nighttime in Shah Alam. Emitted of O_3 precursors from vehicle and industrial might be increase the O_3 concentration in Shah Alam (Leh, Musthafa, & Mohamed, 2014). Therefore, increased of O_3 concentration in urban area influenced by high number of vehicles used.

Figure 3.1 Map of Shah Alam in Peninsular Malaysia (Source: Google Map, 2019)

3.2 Flow of Research Methodologies

Figure 3.2 shows the research flow chart in these research methodologies. This research consist two important parts which were data acquired and data analysis. For data acquisition were carried for three variables of data; hourly O_3 concentration, relative humidity and temperature. Meanwhile, data analysis was carried out for each objective. For the first objective analysis method were used to determine the ozone level, relative humidity and temperature during nighttime. Next, data analysis for second objective was diurnal which investigate the influence of relative humidity towards O_3 concentration. Lastly for third objective, an MLR model was built, relationship between ozone concentration and meteorological factor established.

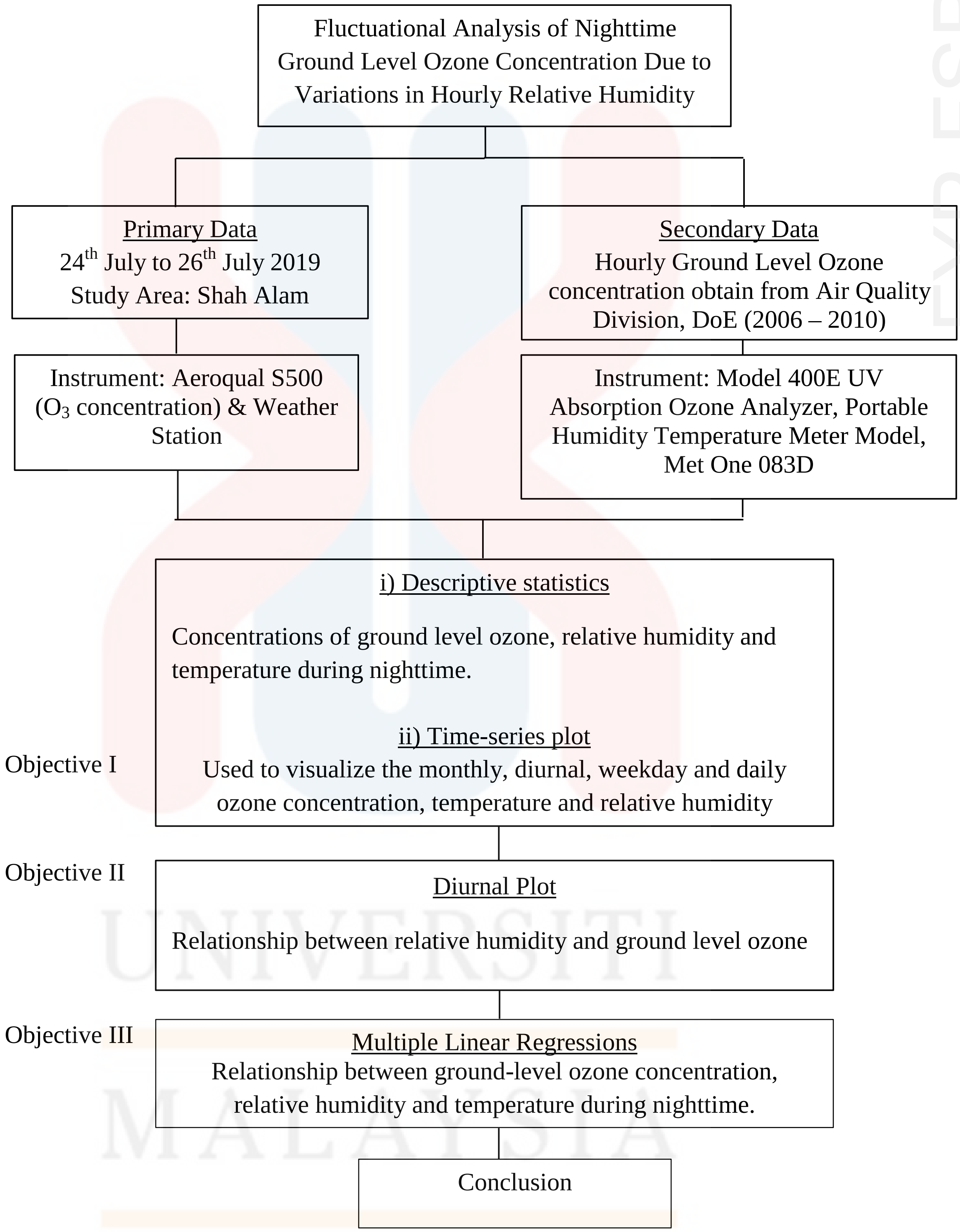

Figure 3.2 Flow of research methodologies

3.3 Data Collection

Primary and secondary data were used to complement this research study. Both primary and secondary data were obtained at same location located in Shah Alam, Selangor on 24th to 26th July 2019.

3.3.1 Primary Data

Monitoring has been done in Shah Alam, data of ozone concentration; temperature and relative humidity were collected using specific instruments. Instruments that used for measured the O_3 concentration was Aeroqual S 500. Small changes in ambient ozone concentration, was detect by Aeroqual S500 that utilized gas sensitive semiconductor (GSS). The range of detection of changes by Aeroqual S 500 in ambient O_3 concentration was 0-0.015 ppm. Aeroqual S500 cannot expose to direct sunlight and rainfall due to it sensitivity and easy to destroyed. A weather station was set up for this research, relative humidity, temperature and wind speed data were collected by its sensors. It may include thermometer sensor that recorded the temperature readings, while hygrometer sensor measured the relative humidity and anemoter measured the wind speed. The weather station was set up at open space 3 m far away between the buildings and about 8 ft from the ground so that anemometers ideally placed to ensure a clear air flow. Both Aeroqual S500 and weather stations was installed for 72 hours.

3.3.2 Secondary Data

Hourly O_3 concentration was acquired from Department of Environment, Malaysia. The ozone concentration data that acquired from DoE were between 2006 and 2010 which recorded using the UV Absorption Ozone Analyzer Model 400A by DOE (Latif *et al*., 2014). Due to high level of O_3 concentration emitted in atmosphere during specific period, these data required regarding to quality of ambient air. The data were sorted according to the scope of analysis. UV Absorption Ozone Analyzer Model 400A was used to measure the small ranges of ozone based on Beer-Lambert stated by Enviro Technology Services. About 254 nm of UV light signals is absorbed by ozone. About 0-100 ppb is the range of ozone that goes through the sample cell. Portable Humidity Temperature Meter Model was another instrument that used by DOE to measured temperature and for relative humidity, Met One 083D was used.

3.4 Data Analysis

In this study data of hourly ozone concentration, temperature and relative humidity in Shah Alam, Selangor was chosen for analyzed. Hourly data of ground-level ozone, temperature and relative humidity from 7.00 p.m. to 7.00 a.m. were recorded. The whole duration for monitoring was 12 hours throughout nighttime. There were totally different variety of analysis that was employed in order to achieve objective of this study such as descriptive method, time-series plot, diurnal plot and MLR were achieved.

3.4.1 Descriptive statistic

Descriptive statistics was used to summarize the data for simply understood. The continual data of hourly relative humidity, temperature during nighttime that influenced ozone concentration, were analyzed by descriptive statistic. Descriptive statistics embrace the standard deviation, variance, the minimum and maximum of the data.

3.4.2 Time- series plot

The monthly, diurnal, weekday and daily ground-level ozone concentration, temperature and relative humidity were inspected visually using this analysis method. In addition, it was utilized the actual time wherever the highest concentration of ozone occurred (Awang, Ramli, & Yahaya, 2015). For y-axis O_3 concentration (ppb), relative humdity (%) and temperature data were plotted, while for x-axis time hours during nighttime from 7 p.m to 7 a.m were depicted for the time series plot for secondary and primary data.

3.4.3 Diurnal plot

The hourly fluctuation of ozone level was investigated optically utilizing according to this method of analysis. In addition, this analysis was used to diagrammatically investigate the variation of O_3 concentration against meteorological factors such as temperature and relative humidity (Awang *et al.*, 2015b). The hourly pattern and period in hours for maximum and minimum concentration and diurnal amplitude was ascertained. For y-axis, data of O_3 concentration (ppb), relative humidity (%) and temperature (°C), while for x-axis, 24 time hours from 7 p.m. to 7 p.m. were plotted for diurnal variations analysis. Present of sunlight during daytime and absence of sunlight during nighttime clearly showed the fluctuations of O_3 concentration in diurnal analysis (Ramli, Ghazali, & Yahaya, 2010).

3.4.4 Multiple Linear Regressions

Multiple linear regressions (MLR) were a statistical technique that used to be a common form of linear regression, in data analysis. Regression that included more than one variable used MLR. This help to decide the relationship between independent and dependent variable. In this analysis, MLR was once used to predict O_3 concentration as dependent variable. There were two independent variables that highly correlated with each other, and for better understanding which independent variable contribute to variance of dependent data, further analysis was using SPSS and multicollinearity was observed through correlations coefficients and VIF.

Formula:

$$y\,(x) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 \ldots + \beta_k x_k + \varepsilon_i$$

Where,

$y\,(x)$	= Dependent variable
x_1, x_2, x_k	= Independent variable
$\beta_0, \beta_1, \beta_2 \ldots \beta_k$	= Coefficient of the regression mode term.
ε_i	= Random error term.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

Based on this research, there were a few of data analysis were conducted. Descriptive analysis, box of whisker plot, time series analysis, diurnal plot and multiple linear regressions were analyses. These statistical analyses were applied to secondary that acquired from DoE and primary data monitoring in Shah Alam.

4.2 Descriptive Statistic of Concentration of O_3, Relative Humidity and Temperature

In this study, descriptive statistics was done and the variation of minimum, maximum, mean and standard deviation of O_3 concentration, relative humidity and temperature of secondary data from DoE was obtained. Result showed that hourly concentrations of ozone during nighttime were below the maximum permissible values as recommended by Malaysian Ambient Air Quality Guidelines (MAAQG) which are 100 ppb for 1-hour average of ozone concentration based on Department of Environment Malaysia (2013).

The low concentration of secondary pollutants such as ozone was influenced by meteorological factors; the increasing of relative humidity and decreasing of temperature. As reported by Tarasova and Karpetchko (2003), lower relative humidity usually corresponds to higher temperatures, higher solar radiation and higher O_3

concentration. Based on Table 4.1, minimum value of O_3 concentration was zero ppb during year 2006 to year 2010. According to the U.S Environmental Protection Agency (2015) zero ppb value of O_3 concentration was categorized under good AQI category. During those five years, in 2009 was measured the highest amount of O_3 concentration up to 91 ppb with minimum value of relative humidity was 38 % and maximum temperature at 34.7 °C. Meanwhile in 2009, the lowest measured amount of O_3 concentration was zero ppb with maximum value of relative humidity was 97 % and minimum temperature at 21.6 °C. Fluctuations amount of O_3 concentration influenced by variations value of relative humidity and temperature. The same finding has been reported by Warmiński and Bęś (2018) stated that decrease rate of O_3 concentration was determined by relative humidity and wind speed.

Table 4.1 Descriptive statistics of ozone, relative humidity and temperature in Shah Alam from years 2006 to 2010.

Year	Parameter	Min	Max	Mean	SD
2006	**Ozone (ppb)**	0.00	83.00	8.64	11.04
	Relative Humidity (%)	43.00	98.00	85.91	8.36
	Temperature (°C)	21.90	34.7	25.56	1.81
2007	**Ozone (ppb)**	0.00	79.00	9.31	11.36
	Relative Humidity (%)	41.00	98.00	87.23	8.89
	Temperature (°C)	20.80	35.10	25.77	1.91
2008	**Ozone (ppb)**	0.00	85.00	9.37	11.14
	Relative Humidity (%)	39.00	98.00	86.99	8.94
	Temperature (°C)	21.60	34.20	25.58	1.86
2009	**Ozone (ppb)**	0.00	91.00	10.98	12.01
	Relative Humidity (%)	38.00	97.00	85.34	9.10
	Temperature (°C)	21.60	34.70	25.96	1.98
2010	**Ozone (ppb)**	0.00	72.00	8.69	11.21
	Relative Humidity (%)	46.00	98.00	86.36	8.03
	Temperature (°C)	22.10	34.30	26.12	1.84

**Note: SD = Standard Deviation; Max =Maximum; Min= Minimum*

4.3 Box and Whisker plot Analysis of Concentration of O_3, Relative Humidity and Temperature

Box and whisker plot were developed to graphically illustrate the variations of ground level ozone concentration. The box and whisker plot of ozone concentration, relative humidity and temperature during nighttime from 2006 to 2010 were depicted in Figure 4.1, Figure 4.2 and Figure 4.3. Based on Figure 4.1, the highest record of O_3 concentration was during February and the lowest record of O_3 concentration during nighttime was in June. The result was influence by meteorological factors such a relative humidity and temperature. According to Hashim, Noor, & Yusof (2018) it stated that, between November to January, northeast monsoon occurred and brings heavy rainfall which indicates high relative humidity value, usually hot weather occurred during February to March. During northeast monsoon and Malaysia considered as wet season and contribute lower pollutants concentration due to high relative humidity and lower temperature. Based on previous study, rainfall indicates high relative humidity that washed out the pollutants (Jayamurugan *et al*., 2013). Malaysia was classified into four seasonal monsoon, different monsoon indicated different values of relative humidity and temperature due migration of trade winds occur, movement of air toward the equator (Webster *et al*., 1998). Malaysia experience northeast monsoon during November to March, while southwest monsoon during June to September while for transitional period, first inter-monsoon during April to May and second inter-monsoon period during October to November (Diong *et al*., 2015). Changes of monsoon influenced the O_3 concentration due to increasing or decreasing of relative humidity and temperature as meteorological factors.

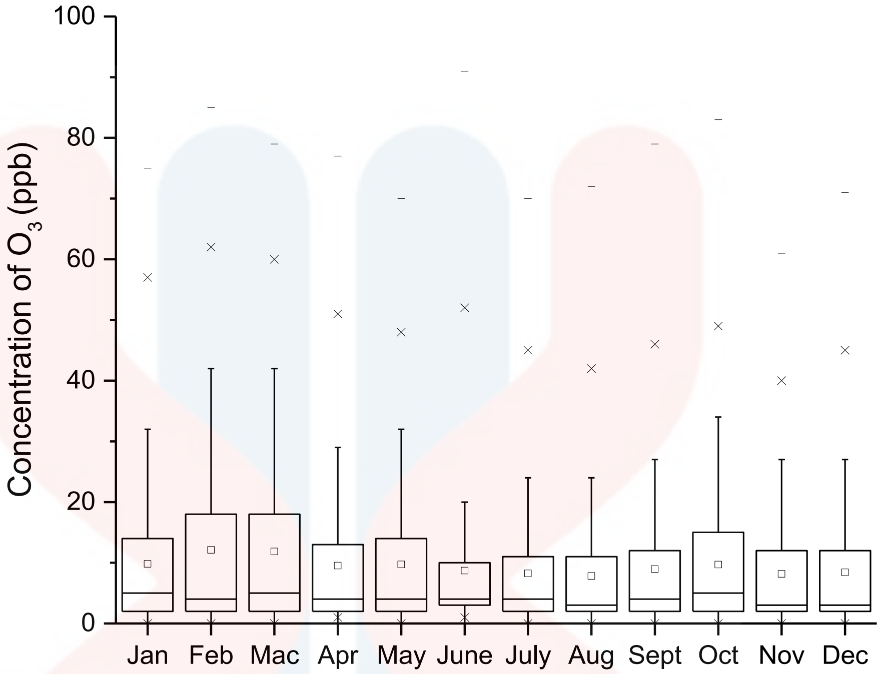

Figure 4.1 Box and whisker plot of average nighttime O_3 concentration in year 2006 to 2010

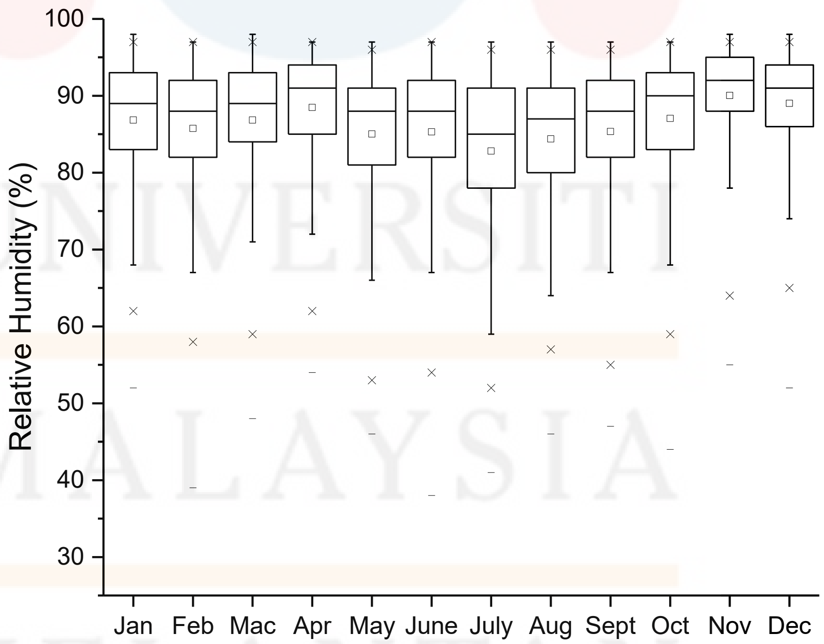

Figure 4.2 Box and whisker plot of average nighttime relative humidity in year 2006 to 2010

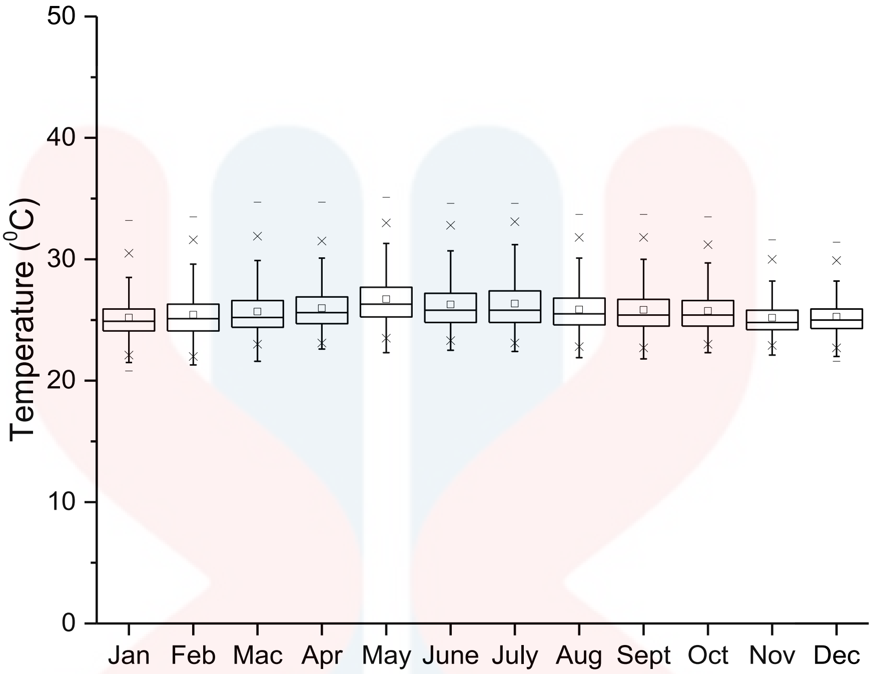

Figure 4.3 Box and whisker plot of average nighttime temperature in year 2006 to 2010

4.4 Time-series Analysis of Concentration of O_3, Relative Humidity and Temperature

The O_3 concentration, relative humidity and temperature in Shah Alam during nighttime in year 2006 to year 2010 were analyzed using time and series plots as show in Figure 4.4, Figure 4.5, Figure 4.6, Figure 4.7 and Figure 4.8. All these past five years data of O_3 concentration, relative humidity and temperature were showed similar trend as visualized in the plot. Based on Figure 4.4 there were some period where missing data during April and May for relative humidity have been recorded, and it believed during the period slightly lower amount of O_3 concentration and lower temperature recorded. It was assumed that, high value of relative humidity in that particular missing data due to lower amount of O_3 concentration and lower temperature in that time. According Valuntaitė *et al.*, (2012) to it showed that high relative humidity (80 %) increased the removal of O_3 concentration.

In June 2009 the amount of O_3 concentration was slightly higher than the others. Other than meteorological factors that influenced the increasing of O_3 concentration, O_3 precursors also indicates variations of its concentration such as NO_X and VOC emission from human activities during daytime also indicates higher amount of O_3 formation. The number of emission in Shah Alam slightly higher than rural areas because of higher number of production in industry that contribute to increasing number of pollutants. Based on previous study stated that Shah Alam located in residential area and surrounding by industrial and its air quality may influenced by industrial pollutants (Siti Zawiyah *et al.*, 2010)

Based on Figure 4.4, showed that increased of relative humidity influenced the decreased the O_3 concentration and there is directly proportional between O_3 concentrations and temperature. Based on previous study, it stated that the shape of ozone cycle was strongly influenced by meteorological conditions and O_3 precursors (Han *et al.*, 2011).

Decreased amount O_3 concentration during late nighttime due to increase relative humidity and precursor for O_3 formation has been used up. In contrast, according to Toh *et al.*, (2013) high temperature, low wind speed, low relative humidity and intense solar radiation can raise O_3 concentration.

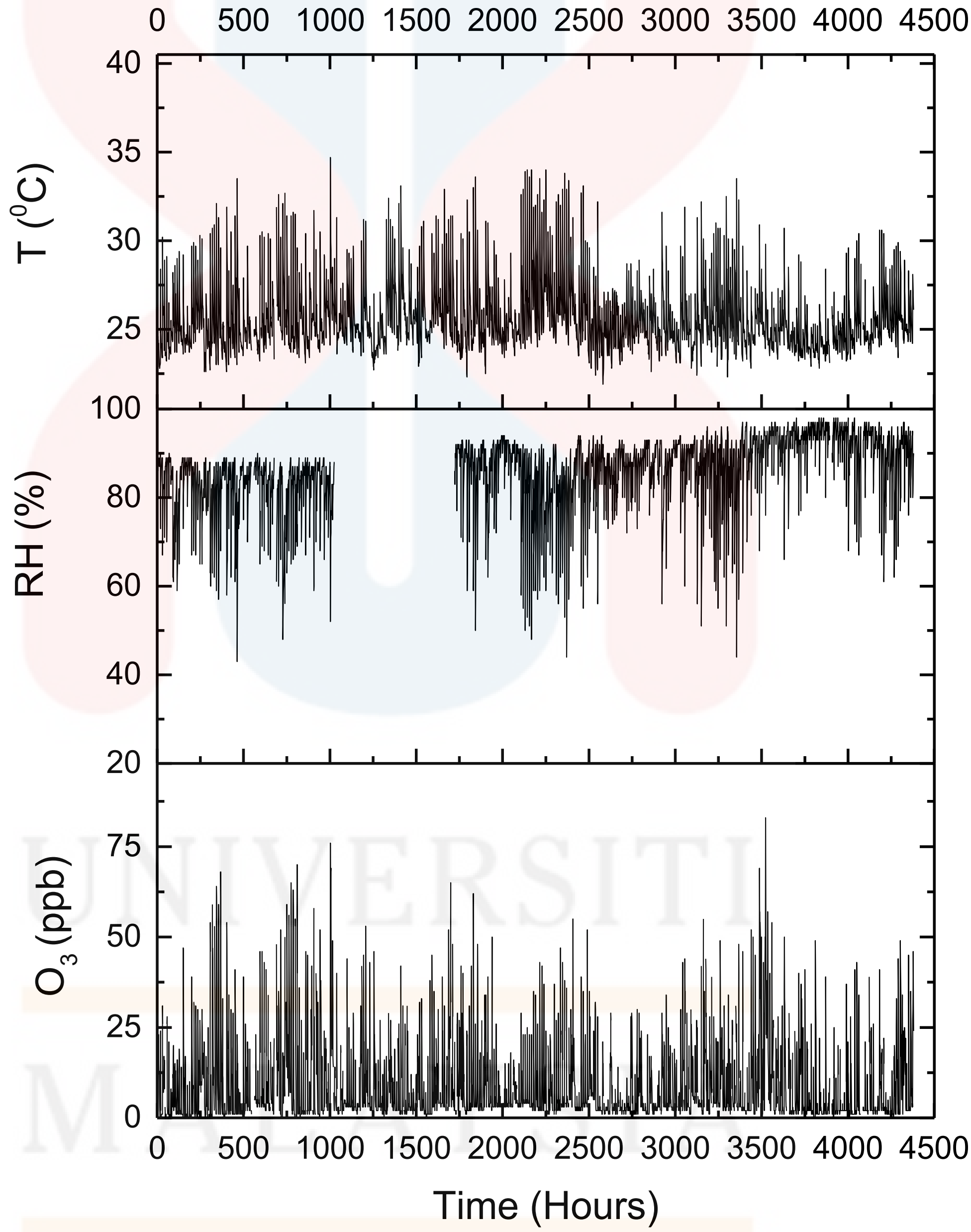

Figure 4.4 Time series plot of nighttime O_3 concentration, relative humidity and temperature in 2006

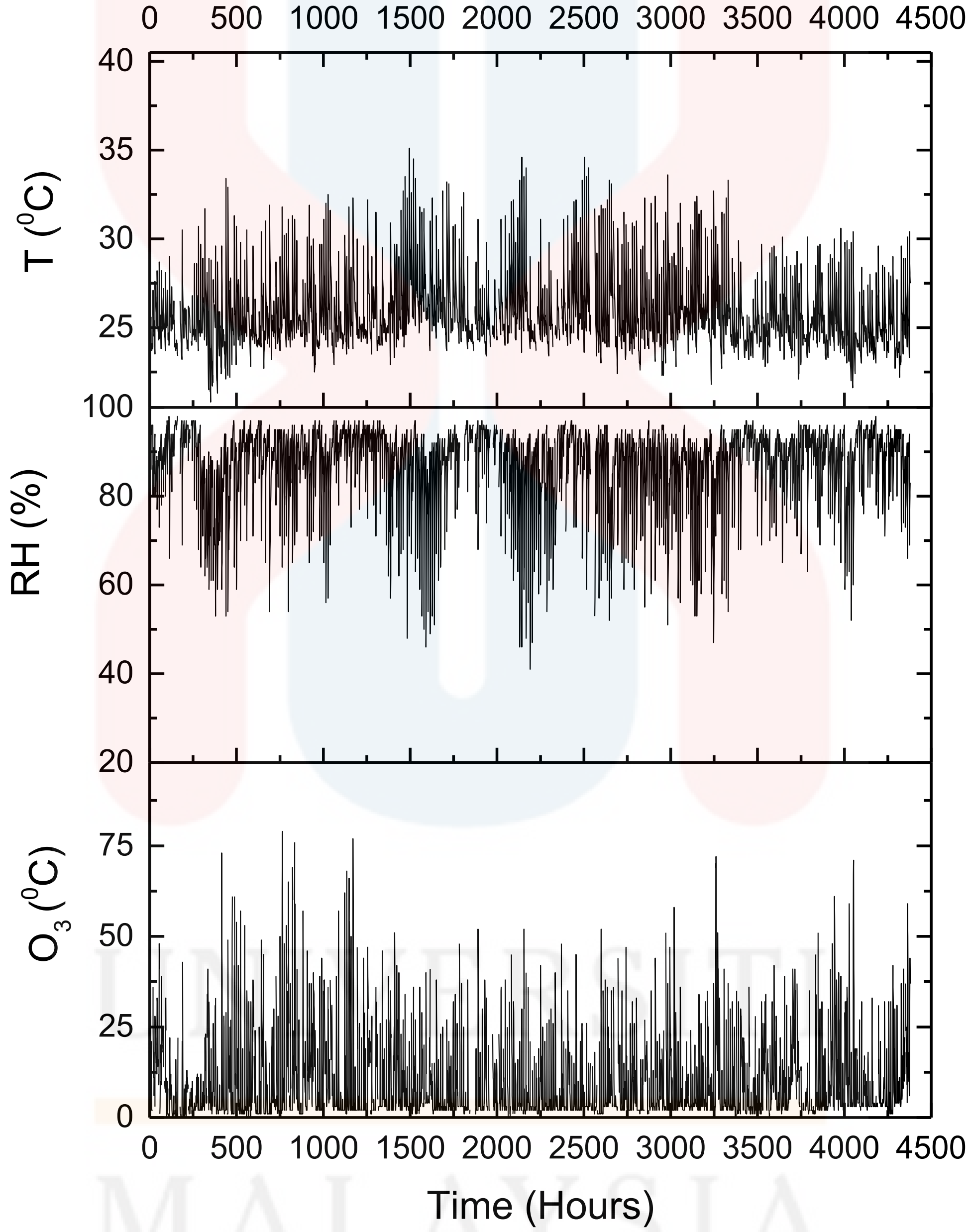

Figure 4.5 Time series plot of nighttime O_3 concentration, relative humidity and temperature in 2007

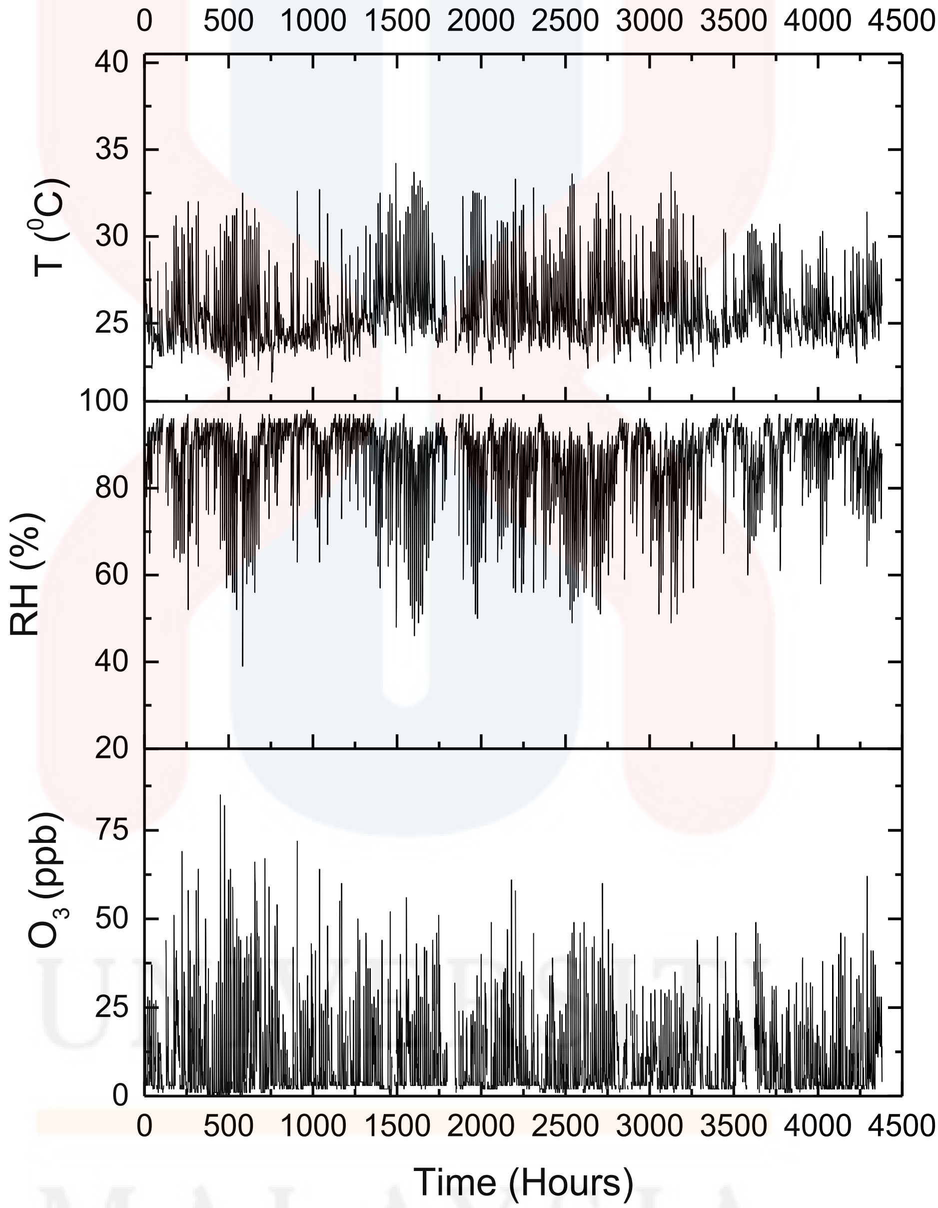

Figure 4.6 Time series plot of nighttime O_3 concentration, relative humidity and temperature in 2008

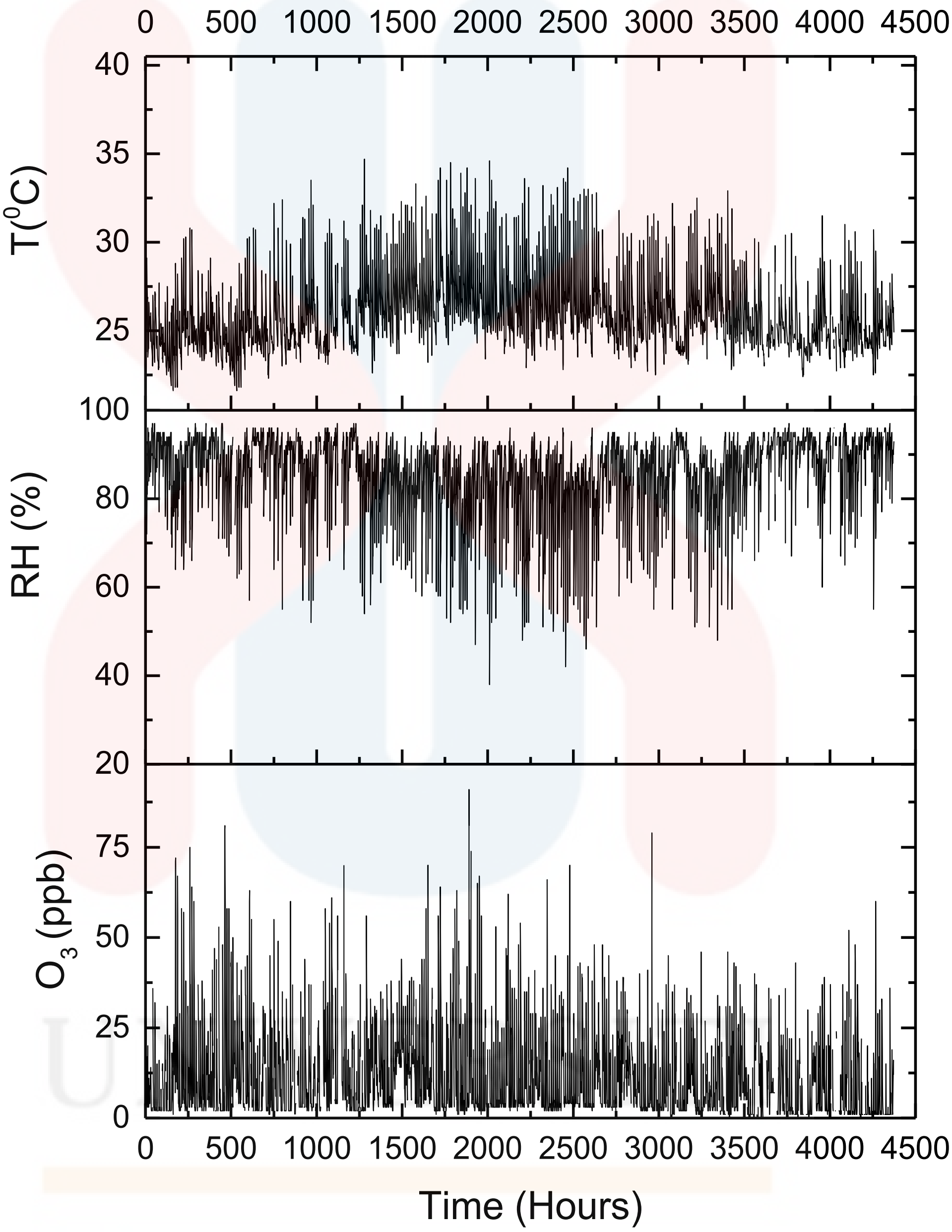

Figure 4.7 Time series plot of nighttime O_3 concentration, relative humidity and temperature in 2009

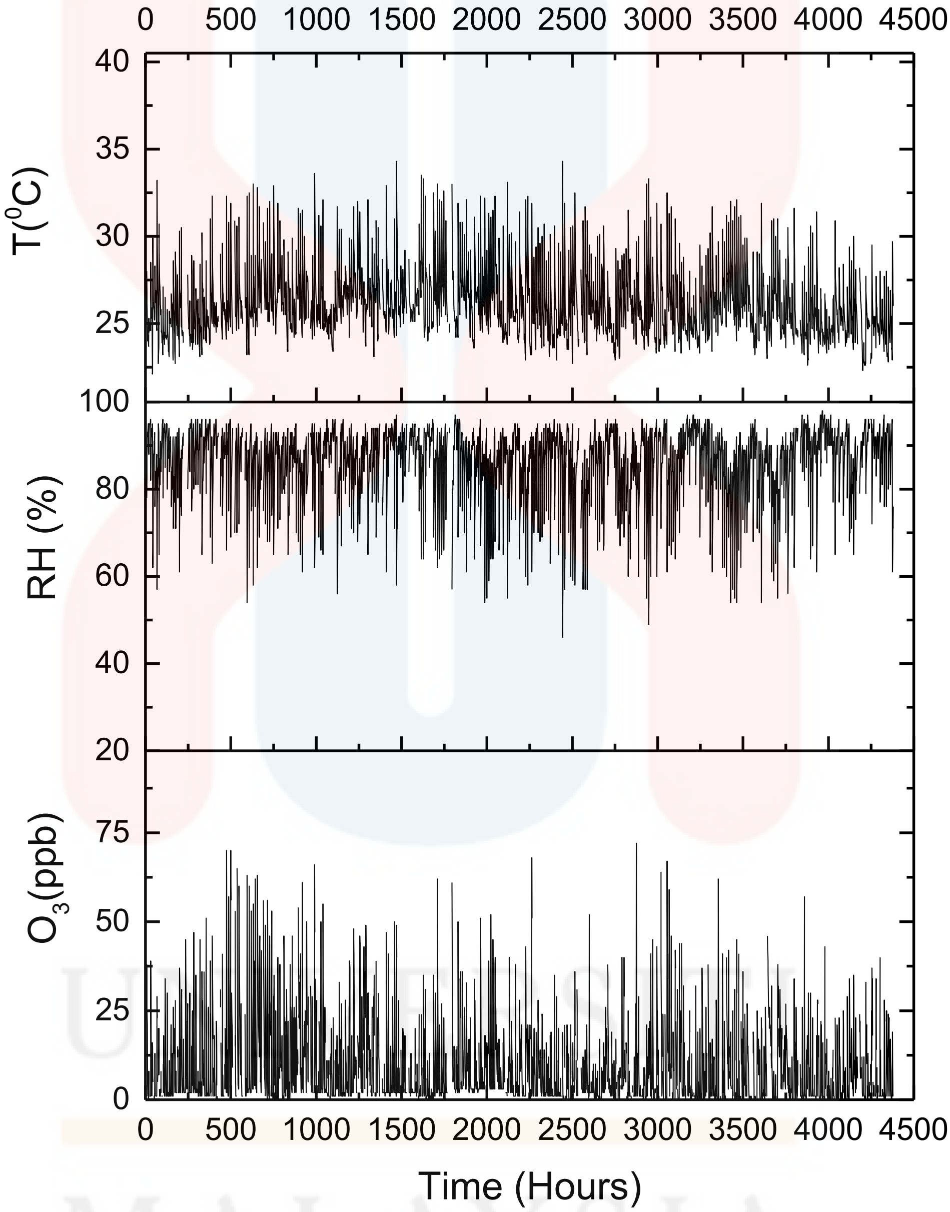

Figure 4.8 Time series plot of nighttime O_3 concentration, relative humidity and temperature in 2010

4.5 Diurnal variations of Concentration of O_3, Relative Humidity and Temperature

The average diurnal plots were produced to analyze the data for 24 hours monitoring during year 2006 to 2010. The graph was shown in Figure 4.9, Figure 4.10, Figure 4.11, Figure 4.12 and Figure 4.13 to visualize the trend of O_3 concentration, relative humidity and temperature. During year 2006 to year 2010, there were similar pattern for diurnal variations and during 2007, concentration of O_3 indicates lower level which was below 55 ppb compared to others. While in 2006, O_3 concentration indicates higher level during daytime which contribute to nearly 65 ppb with lowest amount of relative humidity which below 60 % and temperature slightly increase. The same finding has been reported that the O_3 concentration slowly increase after the sun rises and reaching maximum during the daytime (Han *et al.*, 2011).

The diurnal magnitude for O_3 concentration during daytime was higher than nighttime due to sources of emission and meteorological factors. This was proved by previous research stated that Shah Alam city was covered by higher percentage of industrial and transportation that increase emission of pollutants during daytime (Leh, Musthafa, & Mohamed, 2014). The concentration started increase during peak hour from 12.00 p.m. to 2 p.m. at maximum solar radiation intensity. This could increase concentration of O_3 due to ozone precursor emitted from motor vehicles and industrial on road that influenced the formation of O_3. As reported by previous study, NO_x and VOCs were the most common air pollutants emitted by vehicles and fossil-fuel burning power plants (Amin, Tamima, & Jimenez 2017). The O_3 concentration was slightly decrease during nighttime because of O_3 precursors was efficiently used up for photochemical reaction and there is no production due to absence of sunlight as reported by Han *et al*. (2011).

Based on this research, there was high concentration of O_3 during daytime rather than nighttime and increased of O_3 concentration influenced by decreased of relative humidity and increased of temperature. Based on previous study, increasing O_3 concentration is associated with prevailing meteorological conditions and transport process because the photochemical production of O_3 ceases with the absence of sunlight (Kulkarni *et al.*, 2013).

According to Figure 4.9, Figure 4.10, Figure 4.11, Figure 4.12 and Figure 4.13 clearly show that fluctuation pattern of O_3 concentration influenced by relative humidity and temperature. Reported by Sarkar (2015), relative humidity and temperature were interrelationship with O_3 concentration. Based on Figure 4.10, diurnal plot of O_3 concentration, relative humidity and temperature in 2007, O_3 concentration has the lowest amount during afternoon rather than other four years. Maximal UV radiation during noontime indicates maximum amount of O_3 concentration because of photochemical reactions occurred (Awang *et al.*, 2015b). In contrast, during nighttime the minimum O_3 concentration due to absence of UV radiation and photochemical reaction not occur.

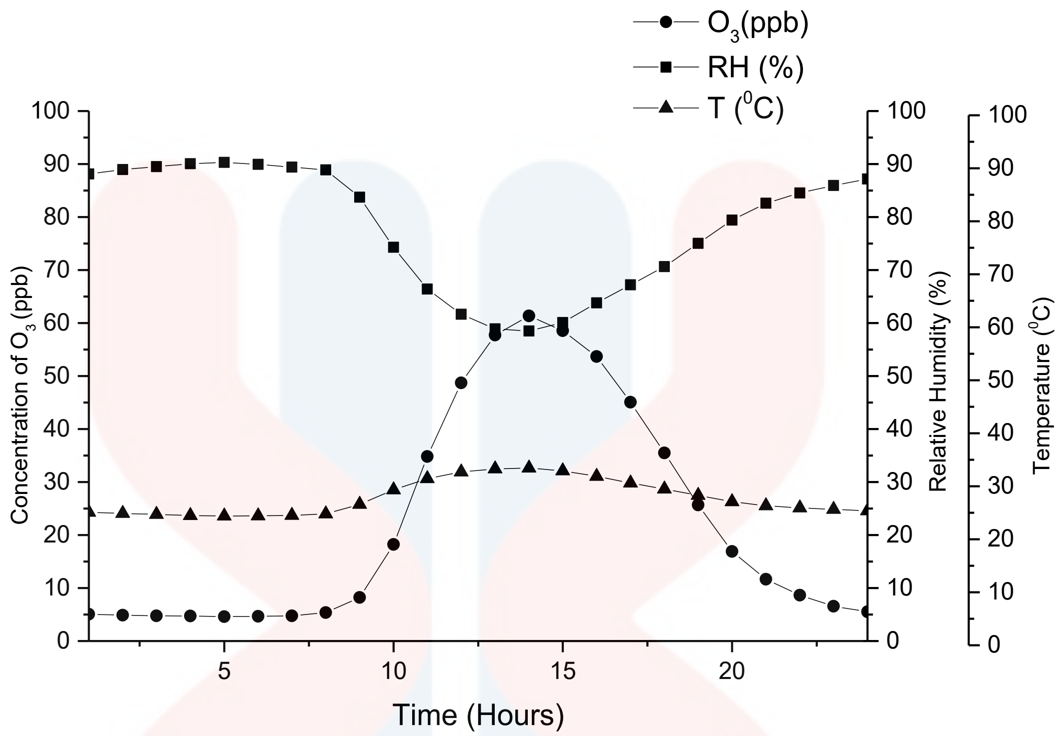

Figure 4.9 Diurnal plot of O_3 concentration, relative humidity and temperature in 2006

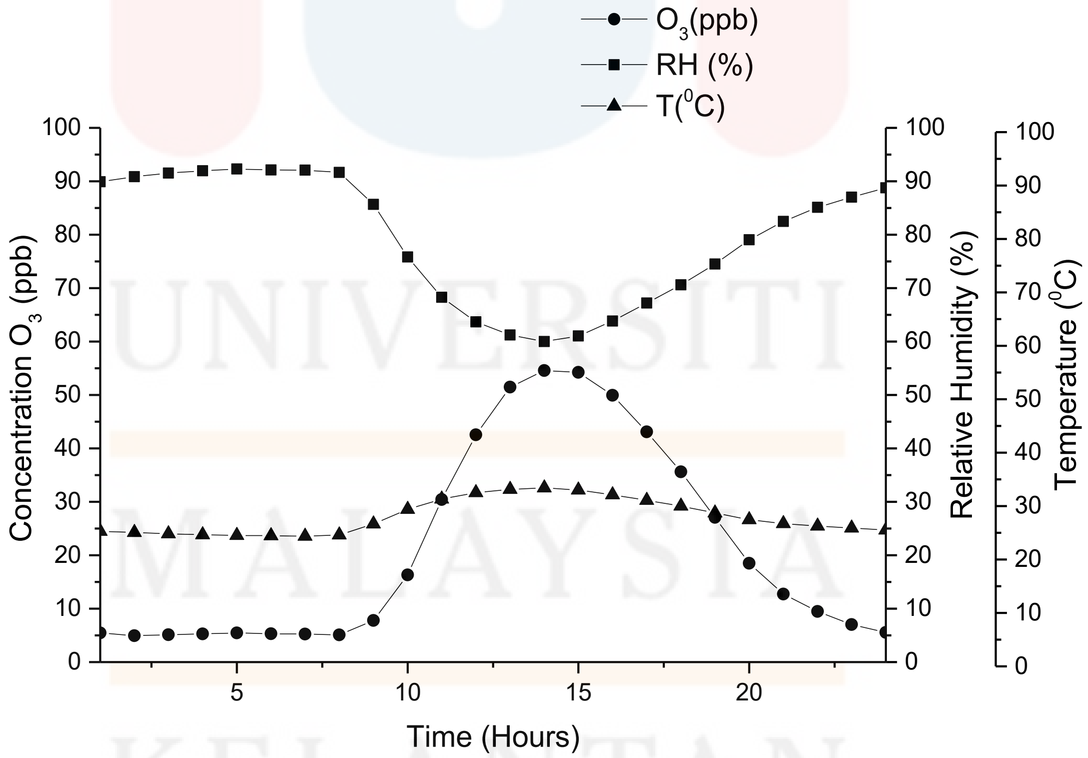

Figure 4.10 Diurnal plots of O_3 concentration, relative humidity and temperature in 2007

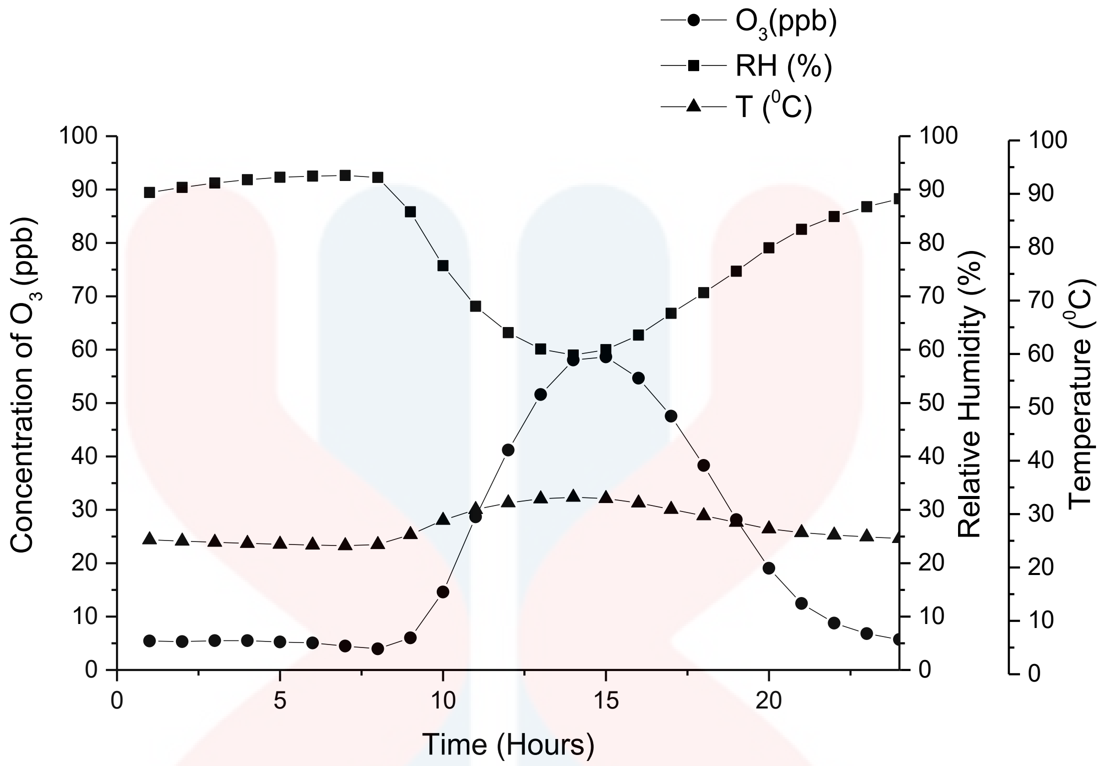

Figure 4.11 Diurnal plots of O_3 concentration, relative humidity and temperature in 2008

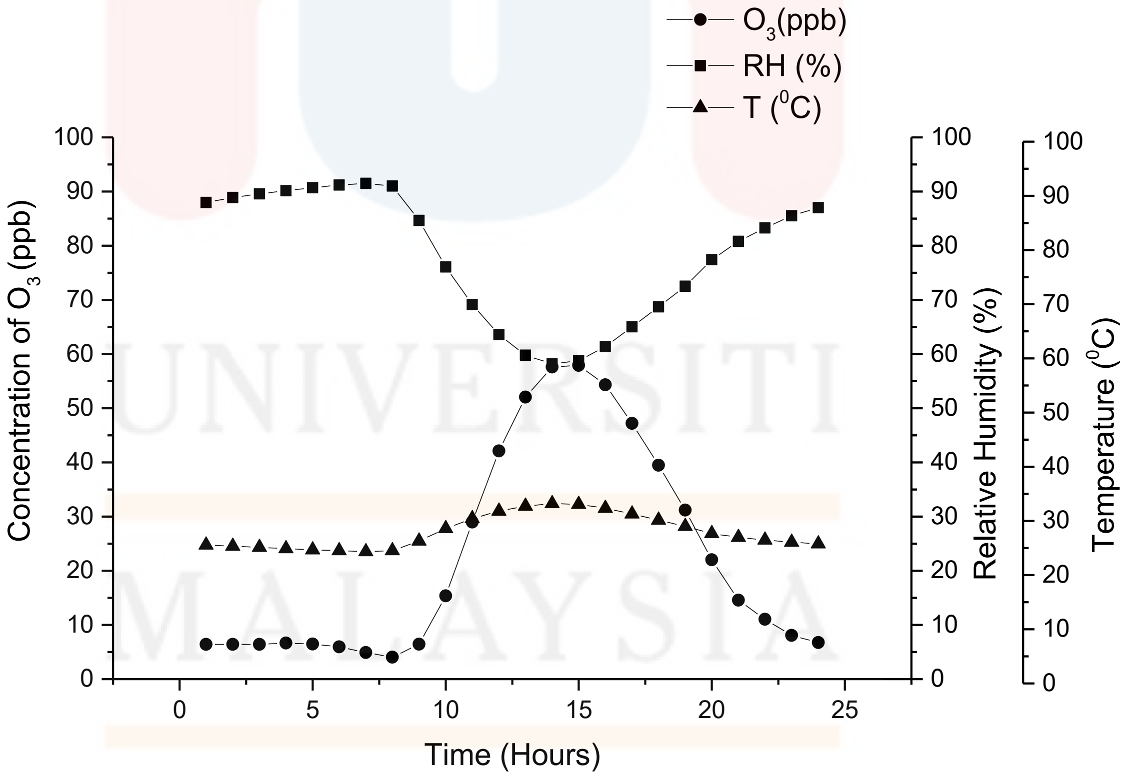

Figure 4.12 Diurnal plot of O_3 concentration, relative humidity and temperature in 2009

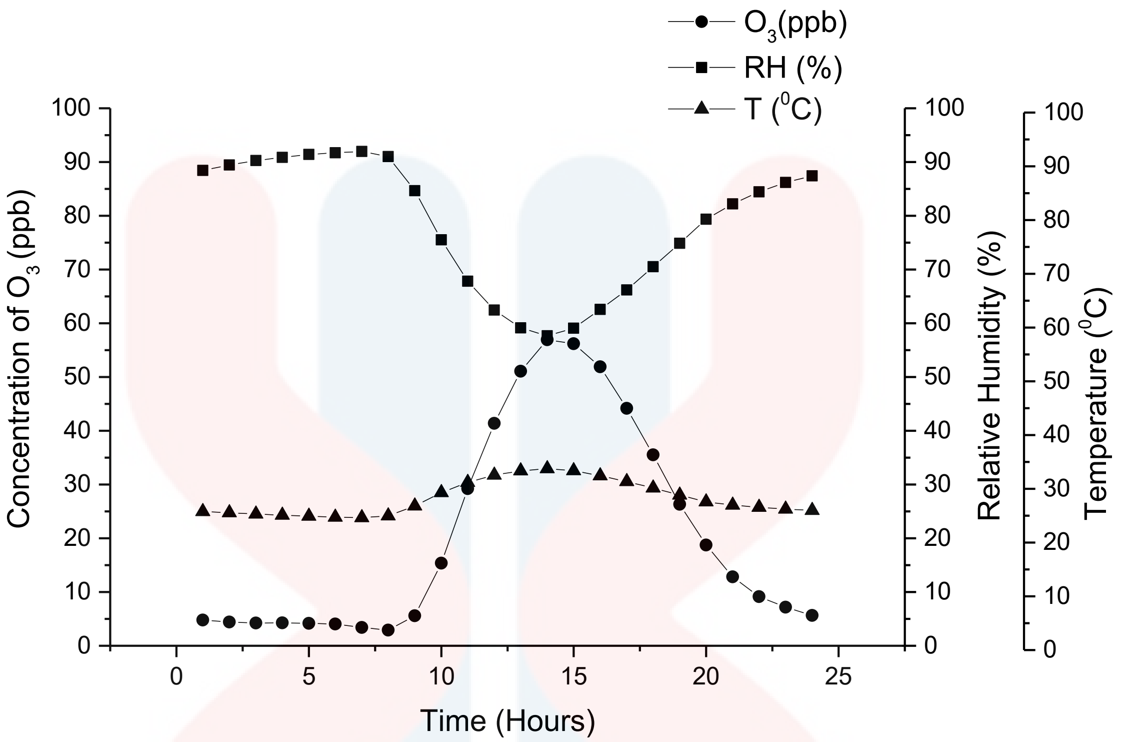

Figure 4.13 Diurnal plot of O_3 concentration, relative humidity and temperature in 2010

4.6 Multiple Linear Regressions (MLR) of Concentration of O_3, Relative Humidity & Temperature

Table 4.2 showed MLR models for Shah Alam using original parameters as input. For multicollinearity and autocorrelation, this data was further analyzed using Durbin-Watson (DW) and VIF. Durbin-Watson is a autocorrelation test that indicates the value between 0 to 4. If the value was 2, it indicates no autocorrelation in residual. While value less than 2 indicates positive autocorrelation and value between more than 2 to 4 indicates negative correlation (Smith, 2019). The value of Durbin Watson was 0.627, which it contributes to positive autocorrelation.

VIF was analyzed for determine its multicollinearity, if the value is exceeding 10 it means that there was serious multicollinearity, and requiring correction (Salmerón *et. al*, 2015). The value of VIF for this study was 2.629. Value of R^2 based on Table 4.2 was describe the proportion variance of dependent variable, if value of R^2 is 1 it indicates the perfect regression model and if the value of R^2 is zero, it is a total failure of regression model. The higher the value of R^2, the better the model fits the data. For this study, the R^2 value was 0.299. It showed that, it is harder to predict O_3 concentration in the future due to meteorological factors and number of emission.

Table 4.2 Summary of Models for O_3 concentration at Shah Alam using secondary data

R^2	Models	Range of VIF	Durbin Watson
0.299	$O_3 = -14.85 – 0.32\ RH + 2.021T$	2.629	0.627

4.7 Verification of Secondary Data Analysis using Primary Data

The secondary data analysis was verified using primary data which has been monitored at Shah Alam. The parameters monitored consisted of O_3 concentration, relative humidity and temperature.

4.8 Descriptive Statistic of Concentration of O_3, Relative Humidity and Temperature for Primary Data

Table 4.3 showed descriptive statistics table of O_3 concentration, relative humidity and temperature in Shah Alam for 24th July 2019 to 26th July 2019. The highest value of O_3 concentration was 66 ppb on day 3 compared to day 1 and day 2. While highest amount of relative humidity was 83.3 % on day 2 compared to day 1 and day 3. According to day 2 and day 3 clearly describe that increased of O_3 concentration influenced by decreased of relative humidity. But for day 1, even though value of relative humidity was lowest than day 2 and day 3, the amount of O_3 concentration was the lowest among there's three. It is due to high wind speed; tend to dilute the emission for ozone formation. Based on previous study in Southern Taiwan, stated that high O_3 concentration due to wind blew weakly from west (<1.5 m/s) (Lo & Hung, 2015). Lower speed of wind decreased the dispersion of ozone precursors indicates less ozone formation (Dawson *et al.*, 2008).

Table 4.3 Descriptive statistics of O_3 concentration, relative humidity and temperature in Shah Alam for 24th July 2019 to 26 July 2019.

Day	Parameter	Min	Max	Mean	SD
Day 1	Ozone (ppb)	3.00	54.00	25.42	9.10
	Relative Humidity (%)	50.40	72.40	63.52	3.79
	Temperature (°C)	30.00	34.70	31.38	0.94
Day 2	Ozone (ppb)	0.00	62.00	6.26	13.38
	Relative Humidity (%)	74.60	83.30	80.83	2.015
	Temperature (°C)	27.40	30.50	28.90	0.69
Day 3	Ozone (ppb)	0.00	66.00	19.46	22.36
	Relative Humidity (%)	61.80	80.50	73.97	5.09
	Temperature (°C)	28.60	33.50	30.63	1.22

**Note: SD = Standard Deviation; Max =Maximum; Min= Minimum*

4.9 Box and Whisker plot Analysis of Concentration of O_3, Relative Humidity and Temperature for Primary Data

Box and whisker plot analysis of primary data monitoring in Shah Alam was analyzed. Primary data was tabulated into three different box and whisker plot according to its parameter. Based on Figure 4.14 highest concentration of O_3 was on day 3 which is 66 ppb and the lowest O_3 concentration was zero ppb on day 2 and day 3. Based on Figure 4.15 highest value of relative humidity was on day 2 which above 80 ppb while the lowest value of relative humidity was below 60 ppb on day 1. Based on Figure 4.15 the lowest value temperature was on day 2 which was below 28°C while the highest value of temperature was on day 1 which was above 34°C.

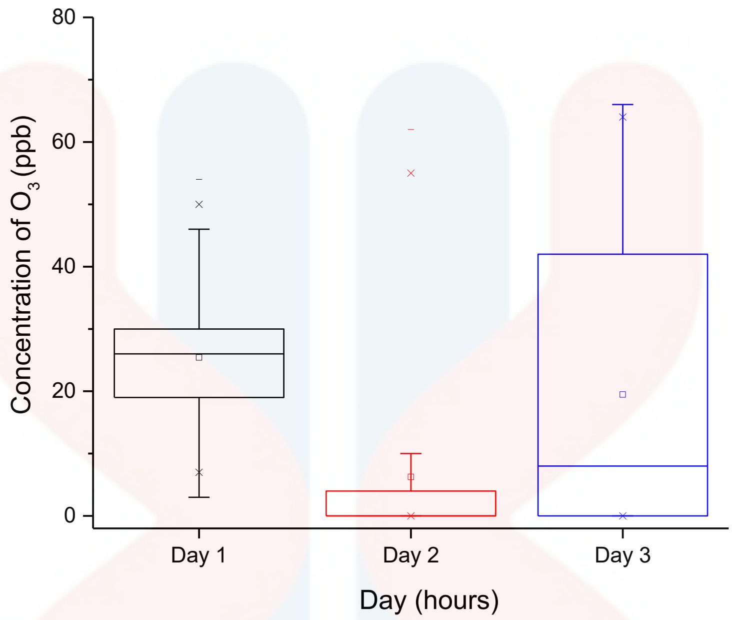

Figure 4.14 Box and whisker plot of O_3 concentration for 24th July 2019 to 26th July 2019

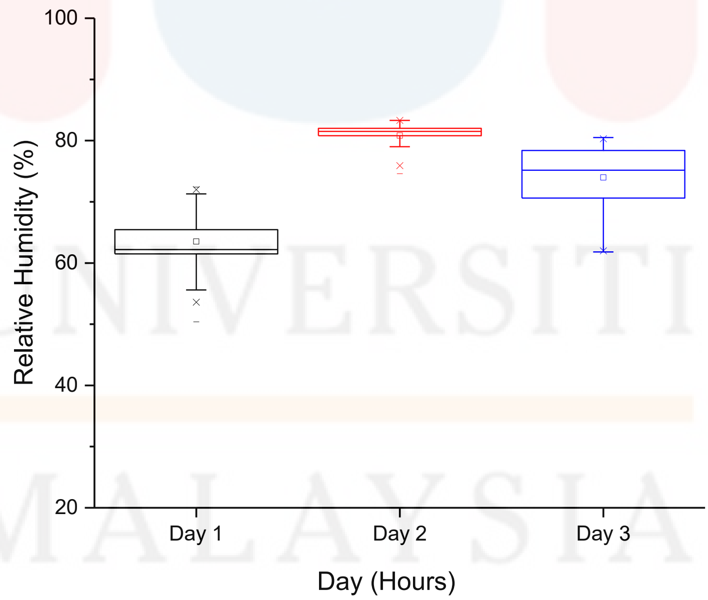

Figure 4.15 Box and whisker plot of relative humidity for 24th July 2019 to 26th July 2019

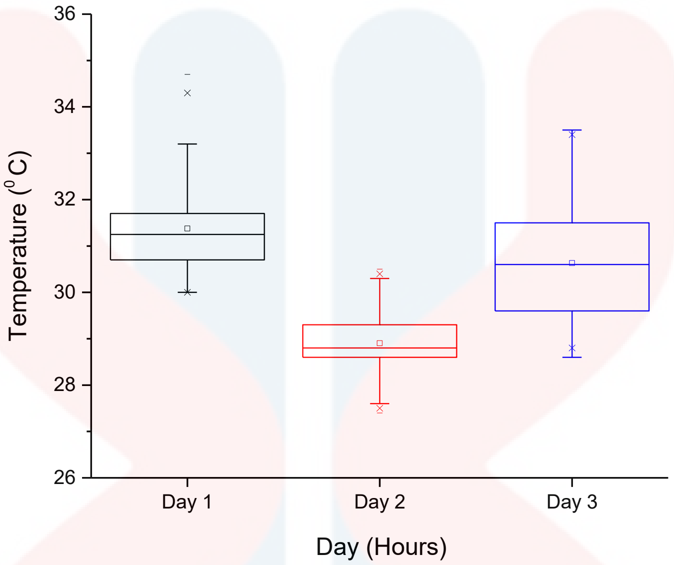

Figure 4.16 Box and whisker plot of temperature for for 24th July 2019 to 26th July 2019

4.10 Time-series Analysis Concentration of O_3, Relative Humidity and Temperature for Primary Data

The O_3 concentration, relative humidity and temperature during nighttime in 24th July 2019 to 26th July 2019 were analyzed using time and series analysis as shown in Figure 4.17, Figure 4.18 and Figure 4.19. Based on Figure 4.17 it show decreasing value of O_3 concentration during nighttime and increasing amount of relative humidity in day 1. The data was tabulated from 7 p.m. to 7 a.m. and there's been less amount of O_3 concentration at 7 p.m. due to ozone precursors has used up for ozone formations. There is absence of sunlight for further production of ozone, It's contribute to low temperature during nighttime and was influenced the concentration of ozone to decrease (Seinfeld & Pandis, 2006). According to Figure 4.18 amount of O_3 concentration on day 2 was above 60 ppb at 7 p.m. which was higher than amount of O_3 on day 1 which was below 50 ppb. The higher the amount of O_3 concentration on day 2 was due to lower amount of relative humidity. The relative humidity at 7 p.m. on day 2 was above 75% while on day 1 only above 50 % relative humidity. The same finding reported by Han *et al.* (2011) decrease of relative humidity indicates increased of O_3 concentration as meteorological concentration given variations of O_3 concentration. Next, according to figure 4.19 there was slightly constant zero ppb amount of O_3 concentration during nighttime due to increasing amount of relative humidity and high wind speed tend to dilute the O_3 concentration. As reported by Dawson *et al.* (2008) decreased speed of wind affected the O_3 concentration.

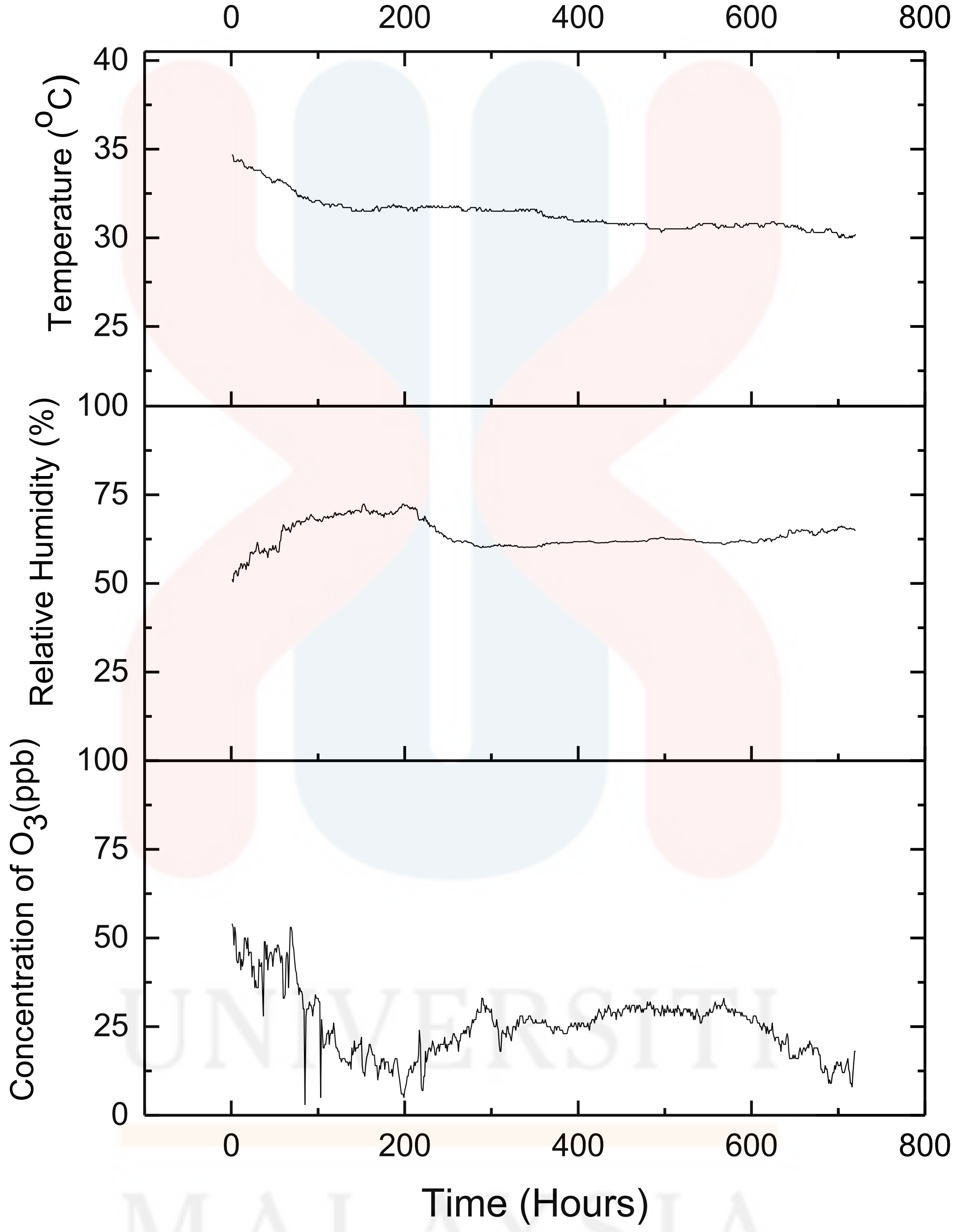

Figure 4.17 Time Series plot of O_3 concentration, relative humidity and temperature for 24th July 2019

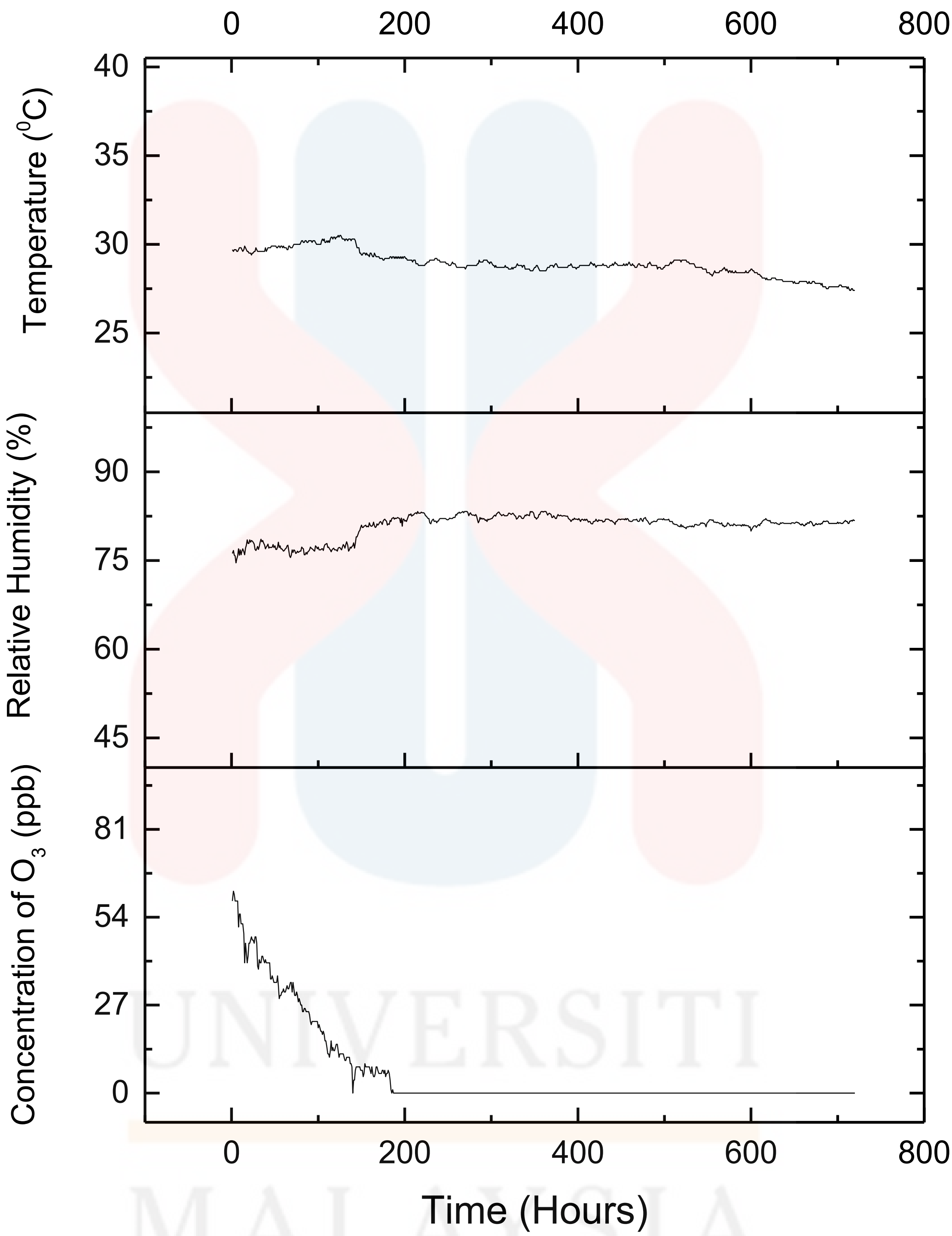

Figure 4.18 Time Series plot of O_3 concentration, relative humidity and temperature for 25th July 2019

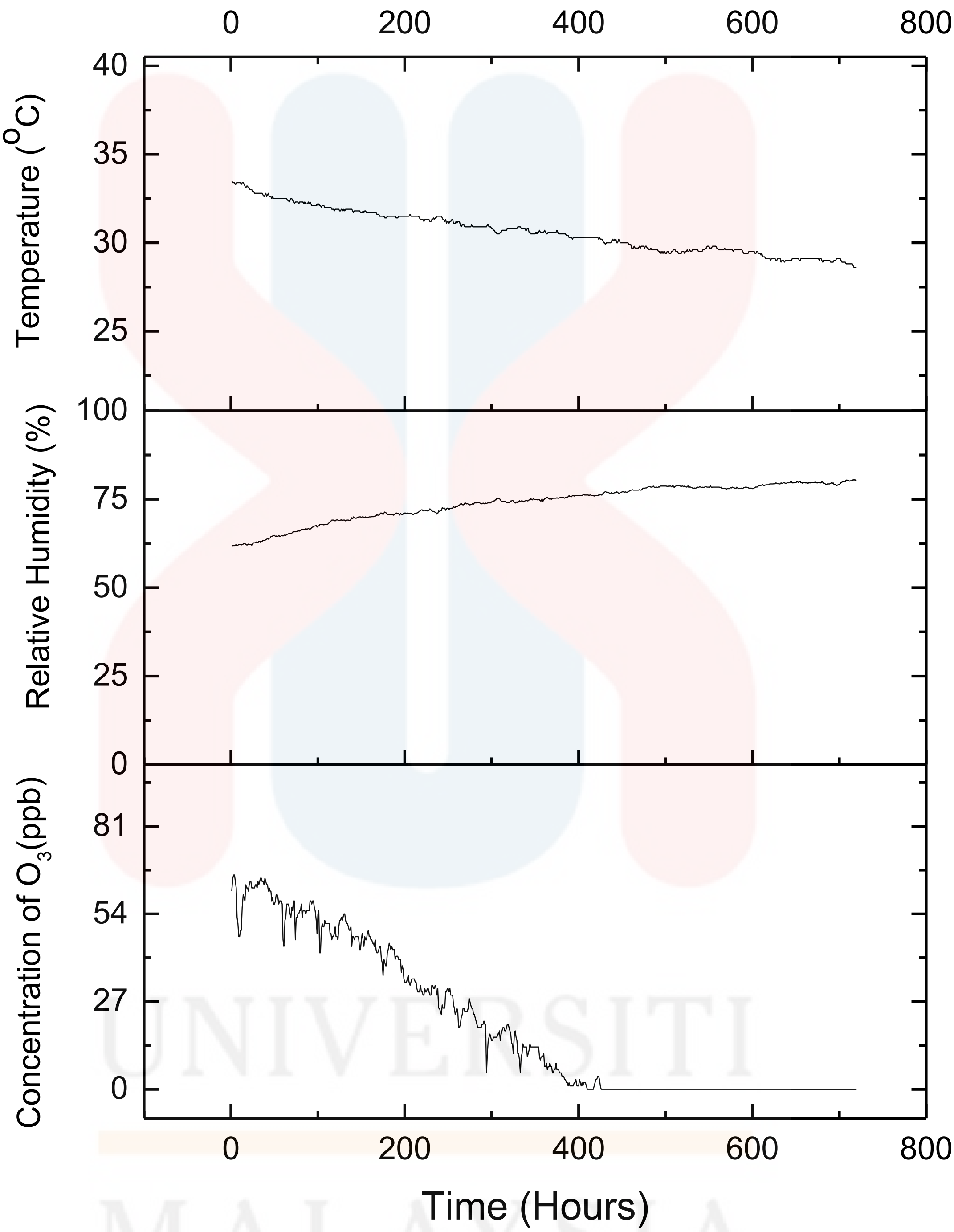

Figure 4.19 Time Series plot of O_3 concentration, relative humidity and temperature for 26th July 2019

4.11 Diurnal variations of Concentration of O_3, Relative Humidity and Temperature for Primary Data

The average diurnal variation of O_3 concentration, relative humidity & temperature for 3 days staring from 24th July 2019 to 26th July 2019 was analyzed. Figure 4.20, Figure 4.21 and Figure 4.22 was demonstrated for 3 days. Figure 4.20 show the highest amount of O_3 concentration above 70 ppb around 12.00 p.m. at noon, highest amount of ozone formation due to ozone precursor from motor vehicles and meteorological factor. Temperature was one of meteorological factor that influenced the amount of O_3 concentration (Gorai *et. al*, 2015). Higher temperature during daytime enhances the ozone formation (Pyrgou, Hadjinicolaou, & Santamouris, 2018). There were missing data of O_3 concentration due to poor of equipment in functioning.

Next, based on Figure 4.21 the highest amount of O_3 concentration was 70 ppb influenced by low value of relative humidity which was 40 % and while the lowest amount O_3 concentration was 0 ppb at influence by slight constant high value if relative humidity which was at 70 % to 80 % . There was increasing amount of O_3 concentration influenced by decreasing value of relative humidity with slightly increase value of temperature. The same finding was reported by Lee *et al.* (2014) stated that maximum amount of ozone concentration significantly influenced by maximum temperature.

Figure 4.22 showed high amount of O_3 concentration which 60 ppb that influenced by low value of relative humidity which was above 60 %. Increased amount of O_3 concentration influenced by decreased value of relative humidity and higher amount of relative humidity indicates lower value of temperature (Dotson, 2018).

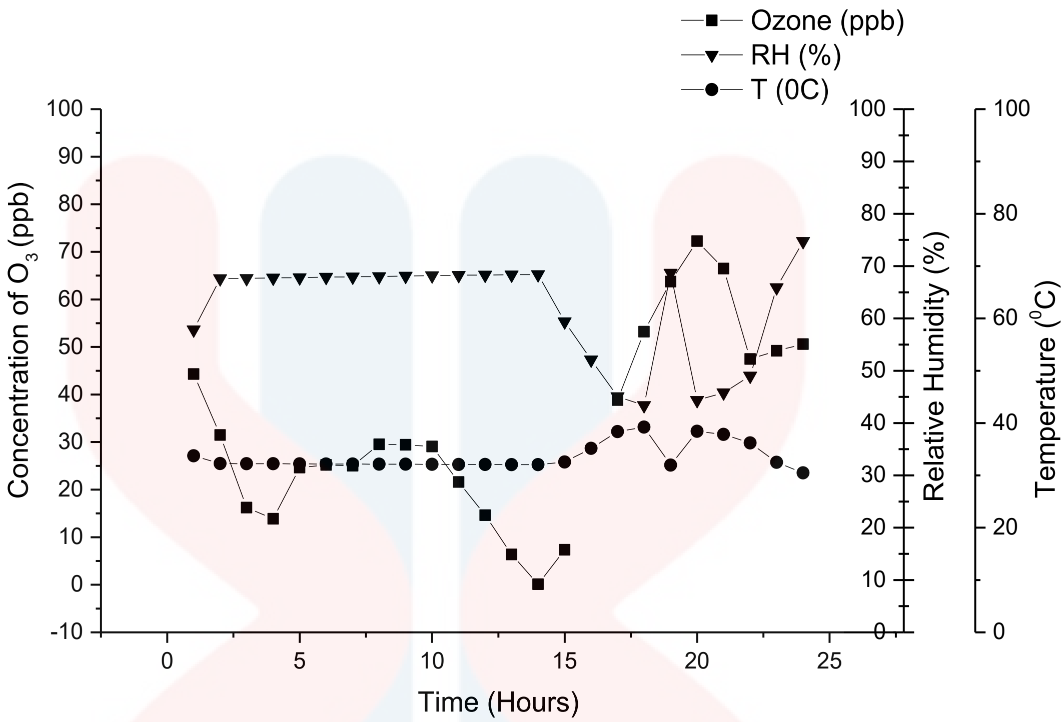

Figure 4.20 Diurnal plot of O_3 concentration, relative humidity and temperature for 24th July 2019

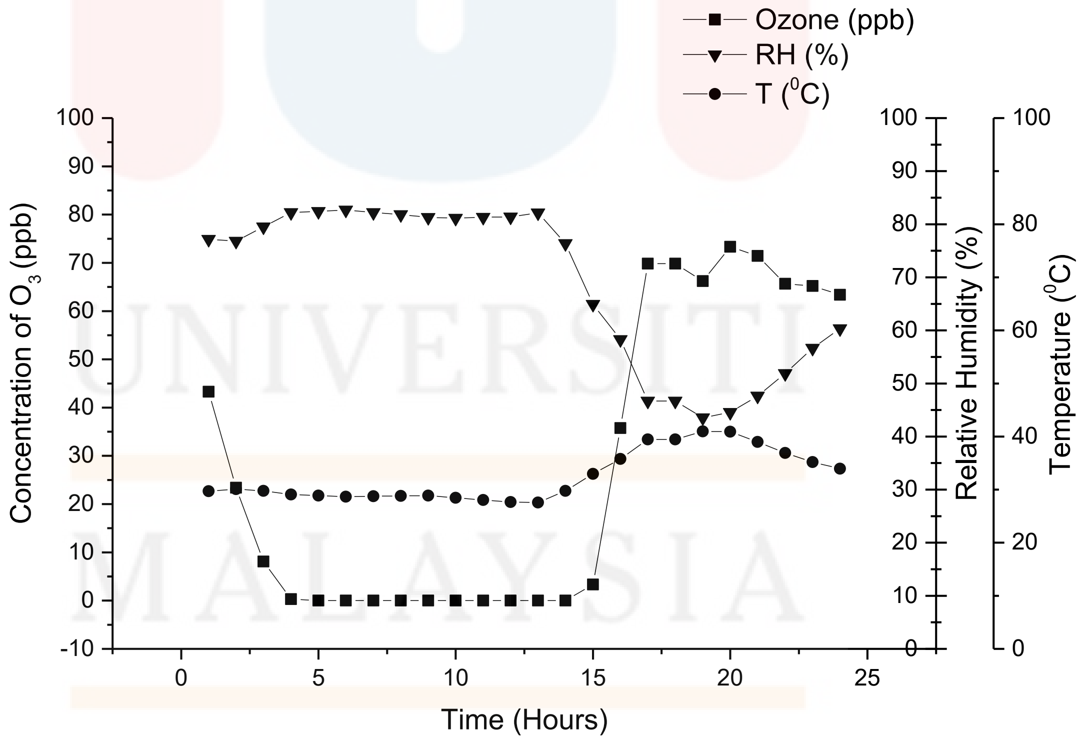

Figure 4.21 Diurnal plots of O_3 concentration, relative humidity and temperature for 25th July 2019

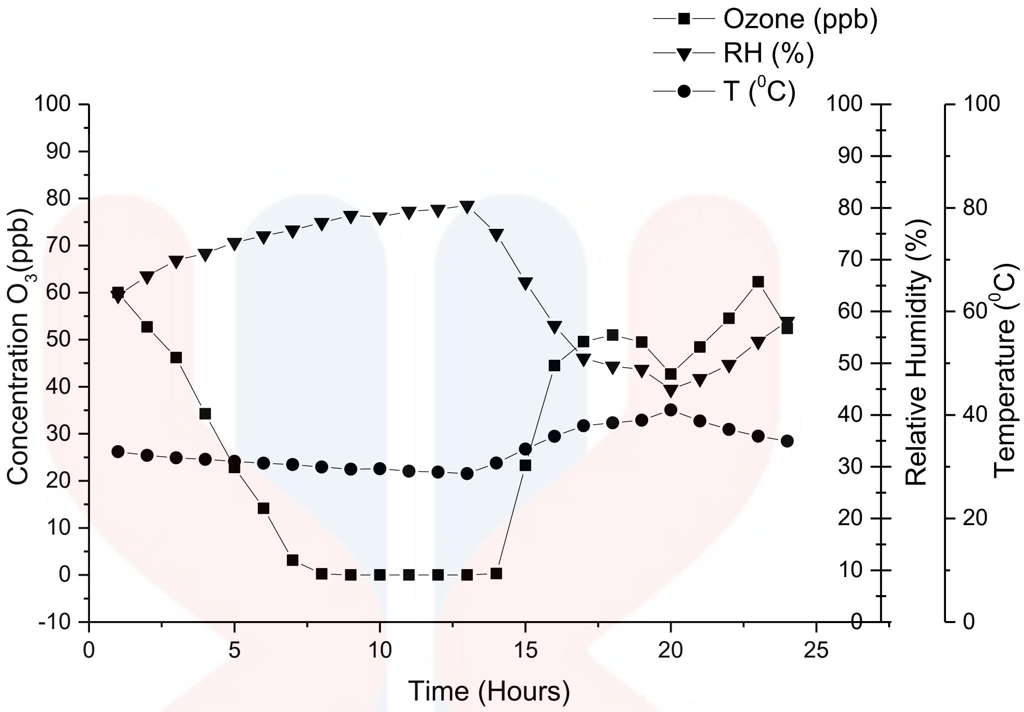

Figure 4.22 Diurnal plot of O_3 concentration, relative humidity and temperature for 26th July 2019

4.12 Multiple Linear Regressions Models (MLR) for Primary Data

Table 4.4 showed the summary of models for O_3 concentration at Shah Alam using primary data. This data was further analyzed using Durbin Watson and VIF. The value of Durbin Watson was 0.508 contribute to positive autocorrelation. Value that indicates the positive autocorrelation was between 0 and less than 2 while for negative correlations, the values was between more than 2 and less than 4. The value for VIF was 1.434 for multicollinearity. The value of VIF not exceeding 10, so it does not required any correction to be done. R^2 value was 0.304, harder for prediction.

Table 4.4 Summary of Models for O_3 Concentration at Shah Alam using primary data

R^2	Models	Range of VIF	Durbin Watson
0.304	O_3 = -192.89 –1.70 RH + 7.446 T	1.434	0.580

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From this research, it can be concluded that the O_3 concentration, relative humidity and temperature during nighttime was determined based on secondary data acquired from DoE from year 2006 to 2010 and monitoring that carried out at Shah Alam as primary data using descriptive statistics and time series plot. The amount of O_3 concentration was not exceed 100 ppb which recommended by MAAQG. Meanwhile the highest mean O_3 concentration was during noontime with 98 ppb in 2006 and 2010. In this research, O_3 concentration displayed normal diurnal pattern which was high during daytime and low during nighttime. MLR models of O_3 fluctuation influenced by relative humidity and temperature was R^2 (0.299). This research showed that, ground level ozone concentration has negative correlation with relative humidity but positive correlation with temperature.

5.2 Recommendation

For recommendation, wind speed data should be acquiring in this research to strengthen the proved that; meteorological factors strongly influence the formation of ozone. For improvement, the instruments for monitoring should frequently check to avoid missing data that will influence the data analysis in time series and diurnal plotting. This study should, investigate other possible sources that contribute to increasing O_3 concentration such as data collection for VOC.

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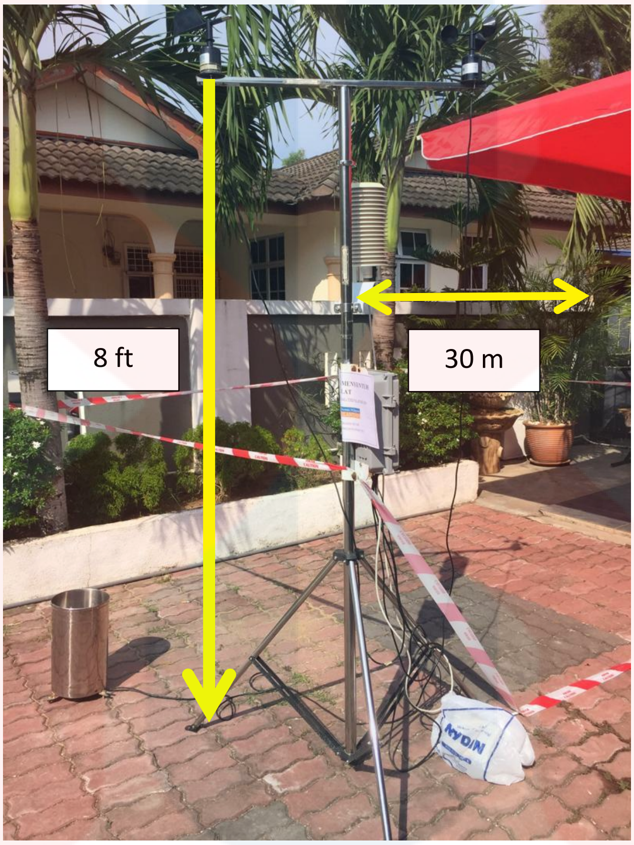
APPENDICES

APPENDIX A

The set-up of weather station during monitoring of O_3 concentration



APPENDIX B

Aeroqual S 500 instrument for O_3 concentration recorded