COMPARATIVE STUDY OF GROUND LEVEL OZONE FLUCTUATION IN URBAN, SUB URBAN AND RURAL RESIDENTIAL AREAS

by

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A report submitted in fulfillment of the requirements for the degree of Bachelor of Applied Science (Sustainable Science) with Honours

FACULTY OF EARTH SCIENCE
UNIVERSITI MALAYSIA KELANTAN

2019

DECLARATION

I declare that this thesis entitled "Comparative Study of Ground Level Ozone Fluctuation in Urban, Sub Urban and Rural Residential Areas" is the result of my own research except as a 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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ACKNOWLEDGEMENT

There are so many people to thank for helping me during the year in completing the requirement Degree of Bachelor of Applied Science (Hons) Sustainable Science. This study help me in enhancing my knowledge and skill in practical especially in atmospheric research. First and foremost, I would like to express my greatest gratitude to my supervisor, Dr. Norrimi Rosaida Binti Awang who support me with all of her inspiration and kindness throughout the semester. With her supportive and thoughtfulness, she make my research smooth in process. I would like to thank you for your support and understanding over these two semester.

I would also like to show gratitude to my examiners for helping me to do the correction of my study. Not to forget Madam Hasifah Binti Abdul Aziz for sharing her knowledge in my research and I am thankful to be able to take in part in the research grant (R/SGJP/A08.00/00874A/001/2018/000497) as research assistant that somehow helping me in completing my FYP especially in my financial. I would to sincerely thank my FYP teammates for their cooperation and help during my research. Not to forget to those who always help me in moral support and inspiration.

Most importantly, none of this could happened without my family. My mother, Yusniza Binti Yusop who offered her encouragement through phone calls every week and the encouragement words to complete my research. This dissertation stands as a testament to your unconditional love and encouragement.

Comparative Study of Ground Level Ozone Fluctuation in Urban, Sub Urban and Rural Residential Areas

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. Ozone and its precursor concentration have become a worldwide issue due to the excessive anthropogenic activities. Therefore, this study focused on the determination of O_3, NO, NO_2 concentrations and meteorological parameters (temperature, humidity, wind speed and wind direction) three residential area namely Taman Tun Dr Ismail Jaya (urban area), Taman Delima (sub urban area) and Taman Kifayah (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 (temperature, humidity, wind speed and wind direction), respectively. The data were monitored at 1 minute average which later converted into 1 hour average. The obtained data were analysed using descriptive statistics to overview O_3 and NO_2 concentration variation, time series plot to show the fluctuation trend in 24 hours and diurnal plot used to determine them in one complete cycle. Wind rose was used to summarize the wind speed and its direction for each site. The concentration of O_3, NO, NO_2 and the meteorological parameters were determined and O_3 concentration was compared by one way ANOVA. The p-value obtained was 0.00 which was less than 0.05 showing there is significant different in O_3 concentration between the residential areas. The mean concentration of O_3 in Taman Tun Dr Ismail Jaya was high (33.3 ppb) but the highest O_3 concentration was recorded in Taman Delima due to open burning activity (35.2 ppb). Meanwhile, Taman Kifayah has the lowest concentration of O_3 (12.1 ppb). However, the ozone concentration at three residential areas were still under permissible level according to RMAAQ.

Kajian Perbandingan Bagi Ozon Paras Tanah dalam Kawasan Perumahan di Bandar, Sub Bandar dan Luar Bandar

ABSTRAK

Ozon (O_3) mempunyai banyak kesan yang buruk terhadap kehidupan manusia, alam sekitar, O_3 terbentuk melalui reaksi fotokimia dengan bantuan cahaya matahari. Kepekatan ozon dan prapenandanya telah menjadi satu isu di seluruh dunia disebabkan oleh aktiviti anthropogenik yang berlebihan. Oleh itu, fokus utaman kajian ini adalah untuk menentukan kepekatan O_3, NO, NO_2 dan parameter meteorologi (suhu, kelembapan udara relatif dan kelajuan angin dan arahnya) serta membandingkan antara tiga kawasan perumahan terletak di Taman Tun Dr Ismail Jaya (kawasan bandar), Taman Delima (kawasan sub bandar) dan Taman Kifayah (luar bandar). Pemantauan udara dilakukan berterusan selama tiga hari dalam masa untuk 24 jam dari pukul 12 pagi hingga 12 pagi setiap hari di setiap kawasan perumahan. Aeroqual siri S500 dan model stesen kaji cuaca RK900-01 telah digunakan untuk mengukur kepekatan O_3, NO, NO_2 dan parameter meteorologi (suhu, kelembapan udara relatif, kelajuan angin dan arahnya). Data dicerap pada purata 1 minit sebelum ditukar pada purata 1 jam. Data yang diperolehi telah dianalisis menggunakan statistik deskriptif untuk tinjauan penuh perubahan kepekatan O_3 dan NO_2, plot siri masa untuk menunjukkan arah aliran turun naik dalam 24 jam dan plot harian yang digunakan untuk menentukan satu kitaran yang lengkap. *Wind rose* digunakan untuk merumuskan kelajuan angin dan arahnya bagi setiap kawan perumahan. Kepekatan O_3, NO, NO_2 dan parameter meteorologi telah ditentukan dan kepekatan O_3 dibandingkan dengan ANOVA sehala. Nilai-p yang diperoleh adalah 0.00 kurang daripada 0.05 menunjukkan terdapat signifikan yang berbeza dalam kepekatan O_3 diantara kawasan kediaman. Purata kepekatan O_3 di Taman Tun Dr Ismail Jaya adalah tinggi (33.3 ppb) tetapi kepekatan O_3 paling tinggi direkodkan di Taman Delima (35.2 ppb) disebabkan oleh aktiviti pembakaran terbuka. Walhal, Taman Kifayah mempunyai kepekatan O_3 paling rendah (12.1 ppb). Walaubagaimanapun, kepekatan O_3 di tiga kawasan kediaman adalah masih di bawah takat nilai yang dibenarkan menurut RMAAQ.

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LIST OF ABBREVIATIONS

ASMA	Alam Sekitar Malaysia Sdn. Bhd
CO	Carbon monoxide
CH_4	Methane
DOE	Department of Environment, Malaysia
hv	Radiant energy
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_X	Nitrogen oxides
O_2	Oxygen
O_3	Ozone
$O(^3P)$	Oxygen atom
OH	Hydroxide
ppm	Part per million
R	Organic radicals
RMAAQ	Recommended Malaysia Ambient Air Quality
OSHA	Occupational Safety and Health Administration
VOCs	Volatile organic compound

MATHEMATICAL SYMBOLS

μ	Mean
σ	Standard deviation
H_O	Null hypothesis

CHAPTER 1

INTRODUCTION

1.1 Background of Study

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 (Singal, 2012). In this modern era, air pollution becoming one of the common problems. The excessive limit of air pollutants in our surrounding, it can cause many detrimental effects on human health. The pollutants concentration that existed in the air gets associated with clean air and hence, air is contaminated.

Atmospheric pollution is caused by both natural and anthropogenic sources. The conventional sources of natural air pollution are volcanoes, biological decay and forest fires. Furthermore, air pollution may arise from another country but the impact of the pollution experienced by another country. The anthropogenic sources are being emitted by traffic and mobile machinery, burning of fuels, industrial processes and others. The majority caused of this source is automobiles due to the combustion.

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. 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). Ozone is also the main component of smog and photochemical oxidant and also considered as a secondary pollutant, (Banan, Latif, Juneng, & Ahamad, 2013).

Ozone occurs in two layers of the atmosphere: - troposphere is the closest layer to the surface of Earth. At this layer, the "bad" ozone or known as the ground level ozone is the air pollutant that harmful and damaging living things that exposed to it. However, the "good" ozone or the stratosphere protects living life on Earth especially from the harmful sun's ultraviolet (UV) rays. The naturally produced ozone in the stratosphere layer keep on being destroyed by man-made chemicals which also referred as ozone - depleting substances. The degradation of air quality that happened in worldwide is caused by one of the air pollutants which is the ground level ozone. According to Malaysian Ambient Air Quality guidelines, the limit of O_3 per hourly is 100 ppb as the basis for assessing atmospheric load in Malaysia.

Meteorological parameters also influenced the formation of ozone. Under hot and sunny conditions ozone appeared to be high due to the favourable condition for photochemical reaction. However, the formation of ozone tends to be lower in wet and cold condition. Other than that, temperature also one of the meteorological parameters that influenced the amount of the production of ozone A large number of observations have depicted that lower (higher) wind speeds increases (lowers) the O_3 concentration levels as it favours the accumulation (dispersion) of ozone molecules (Elminir, 2005).

The ozone concentration in urban, sub urban and rural residential is different. The source or emissions of all sorts of the pollutants in the air also different and varies in the harmful level. The concentration of one area must not exceeded recommended value of Malaysia Ambient Air Quality Guideline (MAAQG) which is

0.06 ppm for an average of 8 hours and during mid-day peak around 2 p.m. until 3 p.m. higher reading of the ozone concentrations were observed (Hashim & Noor, 2017). The concentration of ozone is higher in the urban area compared to in the rural area associated with the meteorological factors in both areas (Banan & Latif, 2011). However, there is a study that shows the recorded data of the concentration of ozone in a suburban area is higher compared to the urban area. The elevation of the ozone concentration caused by the plume consisting of the ozone precursor, NO_x was blown to the sub urban area and low level concentration of ozone in the urban area or the city is because of the process of titration of NO on the ozone surface (Banan et al., 2013).

1.2 Problem Statement

The ground level ozone air pollutants is always involved with air quality degradation especially in urban areas. The high concentration of the ozone level that is produced by the photochemical reaction of its precursors can affect health in many ways. These condition can cause respiratory problem that interfere the lung function and cardiovascular disease (Brunekreef & Holgate, 2000). The air pollution problems due to the urbanization and industrial activities cause the elevation of particulate matter concentrations and poor visibility (Tie et al., 2007). Elevated levels of precursor emissions from various anthropogenic activities, such as transportation and industrialization, can lead to an increase in O_3 concentrations in ambient air (Awang, Elbayoumi, Ramli, & Yahaya, 2016). The meteorological parameters also influenced the concentration of O_3. The comparative study between urban, suburban and rural residential areas of respective concentration of O_3 were conducted to prove the different concentrations of O_3 in the areas. The urban residential is more affected by the active emission of pollutants by the heavy traffic and industrial activities. The population urban residential area is greater in the suburban and rural residential area. The population growth with increasing industrial activities resulting in higher demand for energy and more emission of pollutants into the atmosphere (Geng et al., 2008). The air of the sub urban and rural residential areas also being affected by the activities in the surrounding but those places were less congested of traffic compared to the urban residential area since both residential areas less dense in population.

Different sources of air pollutants that produce ground ozone level in the area contributed to the O_3 and its precursor concentration. The reduction NO and NO_2 emission by either from fossil fuel combustion, industrial or vehicles sources in both urban and rural residential areas will affect the production of O_3 and vice versa (Awang, Ramli, & Yahaya, 2015). The diurnal variations, time series analysis, one way ANOVA of ground level ozone concentrations in urban, sub urban and rural residential areas in 24 hours allowed great understanding of its trend with the meteorological parameters being showed in wind rose.

1.3 Objectives

1. To determine O_3, NO, NO_2 concentrations and meteorological parameters (temperature, humidity and wind speed) in urban, sub urban and rural residential area.
2. To compare O_3, NO, NO_2 concentrations and meteorological parameters (temperature, humidity and wind speed) in urban, sub urban and rural residential area.

1.4 Scope of Study

The location of the monitoring of ground level ozone concentration was at Taman Tun Dr Ismail Jaya in Shah Alam, Selangor as for the urban residential area, Taman Delima, Bakar Arang as the sub urban residential area and Taman Kifayah in Jeli, Kelantan as the rural residential area. At both areas, O_3, NO, NO_2 concentrations and the meteorological parameters which are temperature, humidity and wind speed were measured. The observation of the sources of the air pollutants also been done within the range of monitoring area. The monitoring activity was conducted in 24 hours period in 3 days duration from 12 a.m. until 12 a.m.

1.5 Significant of Study

The comparative study of ground level ozone concentration in urban, sub urban and rural residential areas in 24 hours duration was able to obtain the trend of the concentration of the areas. The variables that affect the concentration of ozone in urban and rural residential areas were determined during the study. The elevation or any decreases of the ozone concentration also being affected by the different sources available at the residential areas. The effect of the ground level ozone concentration towards the living organism and its health been identified through this study. Moreover, the comparison of the data obtained with the standard that had been classified as in Malaysian Ambient Air Quality guidelines showed the level of the ozone concentrations of the sites.

CHAPTER 2

LITERATURE REVIEW

2.1 Ozone

Ozone is a strong oxidant and produce naturally in the Earth's atmosphere. Ozone is made up of three oxygen atoms by a complex series of reactions in the presence of heat and sunlight. Ozone occurs in both stratosphere and troposphere layer (Heuss, Kahlbaum, & Wolff, 2003). Ozone can be good and bad depends on their location. In the stratosphere, the naturally produced O_3 is the good ozone. Most of the O_3 abundantly found in the stratospheric layer situated in the upper atmosphere. These gases formed an ozone layer that protected us from harmful ultraviolet rays.

The troposphere is the lowest part of the atmosphere where ground level or surface ozone is formed with the aid of solar photo dissociation of nitrogen dioxide (NO_2), the oxygen molecule combines forming O_3 (Hamdun & Arakaki, 2015). In this layer, O_3 has a detrimental effect on living's health. However, the accumulation of O_3 in the atmosphere that exceeds a certain limit that cause bad effect on living organisms on Earth is considered as a pollutant. The concentration of O_3 is influenced by the photochemical reaction and the meteorological parameters of the area.

2.2 Ground level Ozone

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 occur via the photochemical reactions between volatile organic compounds and the nitrogen oxides, the ozone precursors with the aid of sunlight. Non-methane hydrocarbons (NMHCs) are the main principle of the atmospheric VOCs and one of the precursor to O_3 generation hydroxyl (OH) radical-initiated oxidation, and subsequent reactions with NO_x (Tang et al., 2008).`

The formation of O_3 also depending on temperature and solar intensity (Abdullah, Ismail, Yuen, Abdullah, & Elhadi, 2017). Ozone in the stratosphere absorbs the short wavelength with radiation of less than 290 nanometers from the sun. Wavelength in range of more than 290 nanometers is allowed to penetrate the troposphere. Ground level ozone is a secondary pollutant that undergoes photochemical reaction of the sunlight and the ozone precursors, NO_x with the presence of VOCs (Abdullah et al., 2017). The ozone is formed in the upper atmosphere which involved the chemical process with the radiant from the sunlight. The formation of the tropospheric ozone involved reactive VOCs which being represented as RH react with hydroxyl radicals (OH) to form R, organic radicals (2.1). The photo dissociation with the aid of solar radiation occurs to nitrogen dioxide (NO_2) release ground state oxygen atoms, O (^{3}p) and cause nitric oxide to reform (2.2).

$$RH + OH \longrightarrow R + H_2O \qquad (2.1)$$

$$NO_2 + h\nu \longrightarrow NO + O\,(^3p) \qquad (2.2)$$

The nitrogen dioxide breaks down into NO and O_3 by the radiant energy with a wavelength of 430 nm (2.3). Hence, O_3 is formed between other free oxygen with an oxygen molecule (2.4). The destruction of O_3 also occurs because of the reaction between the O_3 and NO producing NO_2 and O_3 in the atmosphere (2.5) (Council, 1992).

$$NO_2 + h\nu\ (<420\ nm) \longrightarrow NO + O\ (^3p) \qquad (2.3)$$

$$O\ (^3p) + O_2 \longrightarrow O_3 \qquad (2.4)$$

$$O_3 + NO \longrightarrow NO_2 + O_2 \qquad (2.5)$$

2.3 Ozone precursors

The ground level ozone is not directly formed in the air but with the presence of the sunlight and heat that reacts with nitrogen oxides (NO_x) and volatile organic compound (VOCs) is actually how they formed (Kgabi & Sehloho, 2012). These O_3 precursors which are NO_X emit by the burning of fuel, any human activities that involving burning fuels, combustion of the industrial and vehicles. The photolysis reaction causes the interaction between O_2 and O that created O_3 (Awang et al., 2015).

2.3.1 Nitrogen Oxide (NO_x)

Nitrogen oxides initiates to nitrates and nitric acid as secondary pollutant. The emission of the oxides of nitrogen originates from either natural or anthropogenic sources. The main natural source that produced NO_x is lightning. The NO_X species are the nitric oxide (NO) and nitrogen dioxide (NO_2). Nitrogen dioxide (NO_2) is one of air pollutant that caused health concerns. According to Singal (2012), there are two major ways that cause oxidation of nitrogen which are depending on high temperature of combustion process and they are present chemically in fuel. Hence, at a high temperature of combustion NO_x were released in abundant of amount. Besides the hazards come from the NO_x itself, more detrimental hazards have come from the mixing with precursors which are highly reactive oxidants.

The sum of NO_x which are NO and NO_2 undergoes chemical mechanism during combustion containing vary of chemical reactions (Atkinson, 2000). The mechanisms of nitrogen oxides formation is the stoichiometric ratio and type of nitrous present in the combustion zone depend on it temperature range (Correa, 1993). According to the Zeldovich's mechanism, NO formation is from a stable molecule of high energy to break bonds of O_2 (2.6). An O_3 atom can react with N_2 under slow reaction (2.7). Nitric oxide (NO) form from the N atom liberated a quick react with $O_{2.}$ Nitrogen dioxide is formed when reacted with oxygen (2.8).

$$O_2 + M = O + O + M \quad (2.6)$$

$$O + N_2 \longrightarrow NO + N \quad (2.7)$$

$$NO + O + M \longrightarrow NO_2 + M \quad (2.8)$$

Excessive exposure to nitrogen dioxide can impair the adaptation of our eye to the darkness. The nitrogen dioxide uptake can cause less functioning of pulmonary and lung infection (Othman, 2010).

2.3.2 Volatile Organic Compound (VOCs)

Volatile organic compound (VOCs) concentrations are also increased along with other substances in the air. VOCs are not only organic substances but also volatile and have photo-chemically reactive characteristics. This chemical group are made up of carbon and hydrogen and some other component such as methane, propene and natural gas. The presence of VOCs in several numbers is toxic (Singal, 2012). The emissions of VOC are from the vegetation, industrial and other facilities such as the vehicles that involved combustion. The result of this activity is causing the ozone concentration high which can effect living health (EPA, 2008).

2.3.3 Others precursors of Ozone

2.3.3 (a) Carbon Monoxide (CO)

Carbon monoxide (CO) is a colourless, odourless and tasteless gas. Carbon monoxide is produced during combustion of fossil fuels and biomass and a primary pollutant. The photochemical oxidation of methane and VOCs also indirectly produced carbon monoxide (Wilbur et al., 2012). One of natural activity that became the source of the emission of CO into the atmosphere is the volcanic activity. However, vast amount of CO is emitted to the atmosphere because of the anthropogenic activity from the gasoline-powered automobile usage and other industrial activity.

Carbon monoxide is harmful because of they can cause deprives in heart, brain and other vital organs that need oxygen when it displaces oxygen when they are involved in breathing (Sharovsky, César, & Ramires, 2004). According to OSHA standard (2002) from United States, the workers cannot expose to more than 50 parts per million (ppm) of air contained CO in 8 hours period.

2.3.3 (b) Methane (CH_4)

Methane (CH_4) is gas that widely distributed in nature. They are colourless and odourless gas. Methane is a primary pollutant emitted from different sources. The sources are natural and anthropogenic. Loss reaction for methane in atmospheric is reaction with OH (2.9).

$$CH_4 + OH \rightarrow CH_3 + H_2O \qquad (2.9)$$

Through this reaction, the reaction of OH methane has the order of 8 years lifetime in the lower atmospheres which are the troposphere and stratosphere. The presence of NO_x, O_3 and CO is yield with the rapid oxidation of CH_3 (Dalsøren et al., 2016).

2.4 Meteorological Parameter of Ground Level Ozone

Meteorological parameters influence the concentration of O_3 produced in the air. The parameters involved are temperature, wind speed, wind direction and humidity. The formation, dispersion, transport and dilution of air formation are due to meteorology. The meteorological condition varies at different places. Ozone formation is enhanced during hot and high in temperature which shows that weather condition also influenced it (Kgabi & Sehloho, 2012).

2.4.1 Sunlight

Sunlight played a role in concentrations of ozone in the atmosphere. Ozone has a close relationship with the radiation. Photochemical reactions occur with the aid of sunlight help in the production in the layer of the atmosphere. The solar radiation help in the production of ground level ozone with the series of photochemical reactions between ozone molecules and its precursors, NO_x and VOCs (Seinfeld & Pandis, 2016). The elevated of the solar radiation goes with the increase of the ozone concentration (Kovač-Andrić, Brana, & Gvozdić, 2009). Hence, clear sky and presence of sunlight are the favourable meteorological conditions for production of high concentration of ozone.

2.4.2 Temperature

Temperature can be defined by several definitions (Becker & Li, 1995). Temperature is determining the internal energy of the object or in a cycle of system. Besides that, temperature also can be defined as the proportional to the increase in pressure at constant volume of the gas (Becker & Li, 1995).

Temperature also one of meteorological parameters that influence the concentration of ozone in one area (Punithavathy, Vijayalakshmi, & Jeyakumar, 2015). Temperature has a close relationship with the amount of sunlight to penetrate the Earth's surface to allow disaggregation. Temperature also can increase and aid the propagation of radical chain reactions. A high temperature is the favourable condition of the ozone production. Hence, at a certain time in 24 hours cycle the ozone concentration is the highest in value at its peak concentration (Abdullah et al., 2017).

2.4.3 Relative humidity

Relative humidity is the ratio actual water vapour pressure to the equilibrium at ambient temperature and pressure (Lawrence, 2005). The mean density for a single particle is related to the humidity. Average relative humidity was observed to be minimum in our country because of tropical weather which is dry and humid all year round. In four seasonal countries, relative humidity is low in summer and maximum in autumn and winter (Kgabi & Sehloho, 2012). The production of ozone is most efficiency during low relative humidity due to water molecules that remove the oxygen atom and relatively low content of the water make the number density distribution of electron and the electron kinetic energy of the distribution not affected because of the low water content (Chen & Wang, 2005).

2.4.4 Wind speed and direction

Wind speed and its direction are related to the seasonal pattern. The high production of ozone in the atmosphere is because of reduction of both NO and NO_x concentration in the atmosphere. Increase in the ozone precursors will show inverse behaviour for ozone with wind moving in its direction (Alghamdi et al., 2014). The ozone concentration increases with high wind speed. According to Kgabi and Sehlolo (2012), wind speed study cannot be separated from its direction where the direction of wind indicates whether the ozone concentrations reach any communities in a specific area. The possible sources of the ozone concentration measured indicated from the wind speed.

2.5 Diurnal Trend of Ground Level Ozone

The diurnal pattern or fluctuation pattern in 24 hours duration is crucial information in understanding of O_3 concentrations in the urban and rural residential areas. It can show the variation of pollutant criteria in both areas (Awang et al., 2016) as well as their influencing factors. There are several processes that controlled the exhibition of strong diurnal variations of O_3 which are the photochemistry, deposition and transport (Ghazali et al., 2010). The diurnal variations are affected by physical and chemical mechanisms. The trend of the O_3 can be show and strongly affected by it precursors and the meteorological parameters. The ozone concentrations reach maximum value during afternoon hours with high exposure to the sunlight and decreasing till midnight.

According to Hamdun and Arakaki (2015), the peak time for the formation of the O_3 is during noon from around 12 a.m. to 4 p.m. and start decreasing due to lack of presence of sunlight is around 5 p.m. until 11 p.m. The diurnal variation in the complete cycle shows the trend of the increasing and decreasing of the O_3 concentration. Based on the total hours between the sunrise and sunset is the daylight hour whereas the remaining hours is the night time (Clapp & Jenkin, 2001). The night time based on our country is from 7 p.m. until 7 a.m. Ozone concentration during night time contrast from noontime where the situation or condition is stable with absence of solar radiation. Hence, the O_3 concentration during night time is being influenced by NO_x in the ozone chemistry. During night time, the low concentration of NO_x in one area affected the rate of removal of O_3 causing it to remain high in concentration at night (Awang et al., 2015). The O_3 concentration and formation being influenced by it precursors concentrations included the meteorological parameters. The meteorological parameters consist of the wind speed, temperature, wind direction and humidity. They act as catalyst and aid in the O_3 formation.

2.6 Air pollution in Urban and Rural Areas

2.6.1 Urban area

There are a lot of factors that influencing the concentration of ozone in an urban area. According to the Recommended Malaysian Ambient Air Quality Guidelines (RMAQG), the maximum value of O_3 concentration is 0.10 ppm in averaging time of 1 hour and the mean of the concentration of O_3 in 8 hour averaging time is 0.06 ppm. The emission of it precursors is being influenced by the traffic, vehicles and industry. In recent studies, the ozone concentration in the urban area of Petaling Jaya recorded lower O_3 concentration compared to the suburban area. The reading recorded in 2005 is 140 ppbv (Banan et al., 2013). The concentration is lower compared to the suburban because of the source of NO_x in the city is blown down into the suburban areas. Furthermore, the low of ozone concentration in city area was because of the titration processes of NO on the O_3 surface (Borrego et al., 2006).

2.6.2 Sub urban area

Sub urban area is an area which has less population compared to urban area but more than rural area. This area usually are have less heavy traffic flow compared to the urban area. There are sub urban area have no distinctive trend of ozone fluctuations recorded being compared with the industrial area and vehicular emissions and industrial establishments are the most prominent sources in ozone formation in this area (Awang, Ramli, Mohammed, & Yahaya, 2013). Sub urban area was less exposed to high ozone concentration compared to the urban area. Hence, low in population density and fewer industrial activities results in lower level in a ozone concentration (Ahammed et al., 2006).

2.6.3 Rural area

The rural area is a remote area and less in source of pollutants that influenced the concentration of O_3 and its precursors. Hence, it will show little variation in rural area. Rural area has less in traffic and NO_x emission because of a little amount of industry found in rural area. Hence, NO_x concentration in rural area is very low. According to Hamdun and Arakaki, (2015), under low concentration of NO_x the ozone might photo-chemically destroyed in the troposphere. The source that causes increasing ozone concentration in rural area has the same source in urban areas with different amount of the exposure (Banan & Latif, 2011).

2.6.4 Effect of Ground Level Ozone

There is evidence that ground level ozone has become one of the issues that affect the health of living organisms and interfered in daily human life. Since O_3 is the secondary pollutant, the emission is also due to others factors such as meteorological parameters beside the precursors (Shin, Cho, Han, Kim, & Kim, 2012).

2.6.4 (a) Health effect on humans and animals

The pollutions that are caused by the man- made activities itself caused many effects to living organism's health. Many pollutions remains in our environment in such a long period (Singal, 2012). The exposure of O_3 can cause many effects either it a short term of a long term. O_3 cause asthma attack, lung cancer and reduce mortality (Jerrett et al., 2009). The respiratory system of humans and animals also get affected negatively.

2.6.4 (b) Vegetation

Since ozone is a phytotoxic air pollutant, it also causes detrimental effect towards vegetation all over the world. The oxidisation of O_3 in the plant tissue where the molecules enter through the plant stomata caused the change in the process of biochemical and physiological in a plant (Singal, 2012). Hence, this is one of the reason plants to die. Reduction in photosynthesis and premature leaf loss is one of the effects of O_3 concentration in the environment.

CHAPTER 3

MATERIALS AND METHOD

3.1 Research flow of data collection

Figure 3.1 shows the research flow of the comparative study between three residential areas which are Taman Tun Dr Ismail Jaya, Selangor (urban area), Taman Delima, Bakar Arang (sub urban) and Taman Kifayah, Jeli (rural area) to obtain the concentration of ground level ozone (primary data). The duration for the monitoring at each site is 3 days in 24 hours. The operation hour at each site start at 12 a.m. until 12 a.m. The equipment that being used during the monitoring were Aeroqual S500 series and RK900-01 weather station.

The collected data were being treated accordingly per hourly for three sites. Descriptive analysis, time series plot, diurnal plot and wind rose were used to determine O_3, NO, NO_2 concentrations and meteorological parameters (temperature, humidity, wind direction and wind speed) in urban, sub urban and rural residential area. One way ANOVA was used to compare the concentrations of ozone among the sites.

GROUND LEVEL OZONE IN URBAN, SUB URBAN AND RURAL RESIDENTIAL AREAS

Identify study area in urban, sub urban and rural residential areas.

Experiment set up for monitoring.

Data collection

Data collection

1. The monitoring for the data collection in 3 days duration at the residential areas.
2. Selected area is Taman Tun Dr Ismail, Selangor , Taman Delima, Bakar Arang and Taman Pinggiran, Jeli, Kelantan
3. The operation hour starting at 12 a.m. until 12 a.m. (24 hours).
4. Aeroqual S500 Series to collect $O_{3,}$NO, NO_2
5. RK900-01 weather station collect wind speed, wind direction, temperature and relative humidity.

Data treatment

Objective 1: To determine O_3, NO, NO_2 concentrations and meteorological parameters (temperature, humidity, wind direction and wind speed) in urban, sub urban and rural residential area.

1. Descriptive statistics – To overview the ozone and nitrogen dioxide concentration variation and its variable influences.
2. Time series plot – To show the ozone concentration and its precursors in 24 hours time.
3. Diurnal plot - To determine the trend of ozone concentration in complete cycle.
4. Wind rose - The wind speed and direction (meteorological parameters) that being summarizes the information in map diagram at one place

Objective 2: To compare O_3, NO, NO_2 concentrations and meteorological parameters (temperature, humidity, wind direction and wind speed) in urban, sub urban and rural residential areas.

Analysis of data

5. One way ANOVA – Compare ozone concentration in the urban, suburban and rural residential areas.

Conclusion

Figure 3.1: Research flow of data collection

3.2 Study Area

This research was conducted at three different sites of monitoring stations which were at Taman Tun Dr Ismail Jaya in Shah Alam, Selangor, Taman Delima, Bakar Arang. Kedah and Taman Pinggiran in Jeli Kelantan. The monitoring sites situated at residential areas and in the vicinity of a monitoring station installed and operated by Alam Sekitar Malaysia Sdn. Bhd (ASMA) which is owned by the Department of Environment (DOE).

3.2.1 Taman Tun Dr Ismail Jaya, Shah Alam

Selangor is one of the states in Malaysia which is famous for industrial activities and high population. Shah Alam is a state capital and the state capital of Selangor, Malaysia. This city is situated within the district of Petaling and a part of district of Klang. The total area of Shah Alam is 290.3 km^2 and divided into 56 sections. Shah Alam consist of three parts which are north Shah Alam consists of 18 section, central Shah Alam consist of section 1 until section 24 and south Shah Alam consist of 12 sections that included section 25, section 30, section 31 and section 32. Selangor has a total population of 740,750 people. Shah Alam has tropical rainforest climate with maximum temperature of 31.9 °C and lowest temperature of 23.2 °C. Shah Alam experiences high temperature in March and heavy rains and showers during November. This is because from October to March, northeast monsoon moves in (Buyadi, 2013).

Taman Tun Dr Ismail Jaya (TTDI Jaya) is geographically located on the latitude of 3 °6' 4' North and longitude of 101° 33' 14" East. The residential area is only about 3 km from the state capital and a major township in Klang District. This residential area in the urban area of Selangor is busy and packed with industrial activity. The area experienced heavy traffic due to its location that closed to several industrial parks as well as major highways. In addition, there are schools and business premises surround the area that contributed to high traffic. Figure 3.2 below shows the location of Taman Tun Dr Ismail Jaya through satellite image.

Figure 3.2: The location of Taman Tun Dr Ismail Jaya through satellite image (Google Earth Map).

3.2.2 Taman Delima, Bakar Arang.

Bakar Arang is situated in Kedah with the population of 2,071,900 people. Kedah is located at north western part of Peninsular Malaysia. The total area of Kedah covers 9,000 kilometre squares. Kedah borders with state of Perlis and also have international border with Songkhla provinces of Thailand. Kedah has tropical climate and has a significant rainfall throughout the year. However, Kedah is also one of the states that is claimed as the hottest state in Malaysia.

Bakar Arang is one of state constituency in Kedah. Bakar Arang is one of the areas in Sungai Petani, Kedah. This area is a developing area with industrial activities and residencies. Taman Delima is one of the residential area in Bakar Arang and near to the light industry in the regional. The coordinate of Taman Delima is 53 °8'12"N and 100 ° 27'57"E. Taman Delima also surrounded by the facilities such as school and other facilities. Hence, the area has quite heavy traffic during noon and evening. Figure 3.3 below is the location of Taman Delima through the satellite image.

Figure 3.3: The location of Taman Delima through satellite image (Google Earth Map).

3.2.3 Taman Pinggiran, Jeli

Kelantan located in the north-east of Peninsular Malaysia with the total population of 1.8 million people and about 15,105 km^2 in area. Kelantan is also experiencing a tropical climate with temperature ranging between 21ºC to 32ºC. Kelantan has a variable amount of rain throughout the year. The wet season which is the monsoon is from November to January. Kelantan has ten districts and of them is Jeli district. The total population of Jeli district is 39,445 people and have an area of 1280.21 km^2.

Taman Kifayah is located in a newly developing area of the district where it has the facilities such as hospital and school within the area. This residential area is near to the main road that connects the north and east part of peninsula Malaysia. The main road recorded the surge in traffic. Public and school holidays are where people make inter-state journey. Figure 3.4 below shows the location of Taman Kifayah through satellite image.

Figure 3.4: The location of Taman Kifayah through satellite image (Google Earth Map).

3.3 Monitoring Method

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.

3.3.1 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 0^{o}C until 40^{o}C.

3.3.2 Nitrogen Dioxide

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

3.3.3 Meteorological Parameters

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. Table 3.1 below showed the specific equipment to monitor the O_3, NO_2 and meteorological parameter.

Table 3.1: Detail of monitoring equipment

Types of equipment	The precursors
Aeroqual Series 500	Ozone, Nitrogen oxides
RK 900-01 Weather Station	Temperature, Wind Speed, Humidity

All collected data must always follow the standard quality control processes and quality assurances procedure. As for the Aeroqual, the aeroqual gas and particulate sensors head can be calibrated by factory calibration and manual calibration (McKercher, Salmond & Vanos, 2017). Manual calibration is only for the gas sensors only. As for series 500, the calibration of zero and span of any sensor head can be done by the monitor bases.

3.4 Monitoring Setup for Data Collection

Monitoring been conducted to measure the O_3 concentration and its precursors (NO, NO_2). The meteorological parameters were also will be measured. The monitoring areas were Taman Tun Dr Ismail Jaya, Shah Alam, Selangor, Taman Delima, Bakar Arang and Taman Kifayah, Jeli, Kelantan. The monitoring duration was in 3 days at the sites. The operation hour for collect data is in 24 hours from 12 a.m. until 12 a.m. The instrument used to measure is Aeroqual S500. The function of Aeroqual Series 500 is to collect and monitor average data of the ozone concentration and nitrogen dioxide (Lee & Tsai, 2008). The Aeroqual Series 500 has the sensor head that interchangeable allowed to detect many types of gases. It has different sensors codes, type, detection range and its minimum limit of the detection range. The detection range is 0-0.015 ppm and its minimum detection limit is 0.001 ppm. The detection range for the nitrogen dioxide is 0.1 ppm and its minimum detection limit is 0.005 ppm.

The meteorological parameters which are temperature, humidity, wind speed and wind direction been measured using weather station at both monitoring areas. Table 3.2 and Table 3.3 show the details of Aeroqual ozone and Nitrogen oxide sensor head respectively. Table 3.4 shows the detail of RK900-01 weather station.

Table 3.2: Detail of Aeroqual ozone sensor head

Sensor Code	OZL / OZL2/ OZL4
Range	0-0.5 ppm
Sensor type	GSS
Minimum detection limit	0.001 ppm
Accuracy of factory calibration	< ±0.008 ppm 0-0.1 ppm < ±10 % 0.1-0.5 ppm
Resolution	0.001 ppm
Response time	60 seconds
Temperature	0 to 40^{o}C.
Relative humidity	10 to 90%

Table 3.3: Detail of Aeroqual nitrogen dioxide sensor head

Sensor Code	ENW / ENW2
Range	0-1 ppm
Sensor type	GSE
Minimum detection limit	0.005 ppm
Accuracy of factory calibration	< ±0.02 ppm 0-0.2 ppm < ±10 % 0.2-1 ppm
Resolution	0.001 ppm
Response time	30 seconds
Temperature	0 to 40^{o}C.
Relative humidity	15 to 90%

Table 3.4: Detail of RK900-01 Weather station

Measure item	Measure range	Accuracy
Atmospheric temperature	-40 to 80^{o}C.	± 0.5^{o}C
Atmospheric humidity	0 to 100%	± 3% rh
Wind speed	0 to 60 m/s	± 0.6 m/s
Wind direction	0 to 360^o	5 %
Atmospheric pressure	0 to 110kPa	±0.25%
Rainfall	0 to 800 mm	0.2 mm
Illuminance	0 to 200,000lux	±3 %
Solar radiation	0 to 2000W	< 5%
CO_2	0 to 2000ppm	± 30 ppm
Height	1.8m	
Supply mode	AC220V, AC110V, DC24V, Solar power optional	
Operation temperature	-40 to 80^{o}C.	

3.5 Data analysis

Several techniques were used to analyse data. The concentration of ground level ozone and nitrogen oxide data were analysed using descriptive analysis, time series analysis and diurnal variations. The wind speed and wind direction will be shown in the wind rose analysis.

3.5.1 Imputation of data

Imputation is replacing missing data process with substituted values and occurred during monitoring. Missing data caused problem during the analysis of the data. Mean imputation was used to replace the values for the study. By replacing the missing data with estimated value, imputation can preserves all missing data and once the data is imputed, the data can be analysed using standard techniques (Olinsky, Chen, & Harlow, 2003).

3.5.2 Data Treatment

After the data is being imputed, the collected data were re-arranged to get the average per hourly in 24 hours duration. The data were collected per minute. The average data were collected and re-arranged per hourly in one complete cycle which is from 12 a.m. until 12 a.m.

3.5.3 Descriptive Analysis

Descriptive analysis used to measure the central of tendency of the data which include the mean, median and mode. The analysis also measures the standard deviation, the maximum and minimum value and the skewness which are included in the measures of variability (Investopedia, 2017). The overview of the O_3 concentration and its selected variables can be counted. This analysis was used to overview the ozone and nitrogen dioxide concentration variation and its variable influences. The measures of location are the numeric summaries of the centre of a distribution where mean is the average (Equation 3.1) and median is the middle observation (Berenson et al., 2012). If the sorted data is odd the middle observation is the median otherwise the median is the average of two middle values (Equation 3.2). Standard deviation is the square root of the variance (Equation 3.3).

$$\mu = \frac{1}{N}\sum_{i=1}^{N} x_i \text{ , where } x = x_1 + x_2 + \cdots, x_n \tag{3.1}$$

$$\{(n + 1) \div 2\} \tag{3.2}$$

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2} \tag{3.3}$$

3.5.4 Time Series Plot

The collection of the observation that made sequentially in time is the time series plot. The order of observation in time series analysis is critical to avoid any errors in the establishing data (Lee et al., 2003). Time series plot is suitable to show the continuos data which involve the duration of specific time. The data was used to show in the time series data is the ozone concentration and its precursors. The concentrations of O_3 of the study areas were compared with the permissible values as recommended by Malaysian Ambient Air Quality Guidelines (MAAQG) (Awang et al., 2016).

3.5.5 Diurnal Plot

Diurnal variations were used to show the trend or pattern of O_3 concentration with time. The relation between the concentrations of O_3, its precursors and the meteorological parameter were shown by the composite diurnal plot. The highest concentration of O_3, was shown in the diurnal plot for each site. The information on the chemical formation or destruction as well as the sources of O_3 was provided through the diurnal variations of O_3. The shape of O_3, cycles was strongly affected by its precursors and the meteorological conditions.

3.5.6 Wind Rose

Wind rose is suitable to use to show the wind speed and direction that summarizes the information in map diagram at one place. The wind rose can show the relative frequency and the percentage of time of the wind blows from specific direction during the observation of the study. Commonly, wind rose consists of eight radiating lines which the length is proportional to the frequency of wind and the thickness of the lines will show the wind strength. Basically, the meteorological parameters at three areas will be shown using the wind rose. The magnitude and spatial distribution of the wind or pollutant deposition will strongly influenced the wind rose model (Carslaw & Ropkins, 2012).

The same distribution shown in the wind rose suggests that the same source of all pollutants and same wind direction from the surrounding to the monitoring area (Gvozdić, Kovač-Andrić, & Brana, 2011). The range of the wind speed with the maximum value were shown in the wind rose with its direction.

3.5.7 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 et.al.,2009). One way ANOVA is required since its involved three residential areas which is more than two groups (Ross & Willson, 2017).

The significance difference among the groups can be determine by one way ANOVA through the assumptions made to prove the data. There are independent variable and dependent variable in an ANOVA but only one independent variable is considered in one way ANOVA (Green, 2016). One way ANOVA will be used to compare the collected data in urban, sub urban and rural residential areas.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

Several statistical analyses has been conducted in this study. The analyses are descriptive statistics, time series plot, diurnal plot, wind rose and one way ANOVA.

4.2 Descriptive statistics

The variation concentrations of ozone and nitrogen dioxide of 24 hours in three days in three different respective residential areas were studied using descriptive statistics. Descriptive statistics used to obtain mean, standard deviation, the maximum and minimum value of the data in three residential areas. The descriptive statistics for ozone (O_3) and nitrogen dioxide (NO_2) concentrations were recorded along with the meteorological parameters as shown in Table 4.1, Table 4.2 and Table 4.3.

Table 4.1: Descriptive analysis of urban residential area, Taman Tun Dr Ismail Jaya, Shah Alam

	Shah Alam											
	Day 1 - 14/2/2018				**Day 2 - 15/2/2018**				**Day 3 - 16/2/2018**			
Parameter	Mean	Standard deviation	Min	Max	Mean	Standard deviation	Min	Max	Mean	Standard deviation	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
Temperature (℃)	28.3	3.1	25.0	34.0	28.9	4.0	24.0	35.0	29.7	3.6	25.0	36.0
Relative Humidity (%)	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 4.2: Descriptive analysis of sub urban residential area, Taman Delima, Bakar Arang.

Bakar Arang												
	Day 1 - 25/7/2018				Day 2 - 26/7/2018				Day 3 - 27/7/2018			
Parameter	Mean	Standard deviation	Min	Max	Mean	Standard deviation	Min	Max	Mean	Standard deviation	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
Temperature (℃)	28.8	3.5	25.0	34.0	29.5	2.8	26.0	34.0	28.3	1.8	26.0	33.0
Relative Humidity (%)	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 4.3: Descriptive analysis rural residential area, Taman Kifayah, Jeli.

Jeli												
	Day 1 - 14/8/2018				Day 2 - 15/8/2018				Day 3 - 16/8/2018			
Parameter	Mean	Standard deviation	Min	Max	Mean	Standard deviation	Min	Max	Mean	Standard deviation	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
Temperature (℃)	28.5	4.2	23.0	36.0	28.9	4.5	23.0	36.0	28.9	4.1	24.0	36.0
Relative Humidity (%)	67.0	12.8	45.6	81.8	65.4	13.2	45.4	81.6	66.7	12.7	44.8	81.7

The results showed 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.

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, Tmana Tun Dr. Ismail Jaya showed the highest mean of ozone concentration with 33.3 ppb on second day while the lowest mean of ozone cocentration 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 factor of the maximum ozone in this residential area.

4.3 Hourly variations of pollutants and meteorological parameters in residential areas

The hourly variations of the ozone, nitrogen dioxide and volatile organic compound concentration and meteorological parameters (temperature and humidity) concentrations in three residential areas were analyzed using the time series plots as shown in Figure 4.1, Figure 4.3 and Figure 4.5 hourly for three days. The time series plot showed the trend for three different areas in three days. The ozone, nitrogen dioxide and volatile organic compound concentrations and meteorological parameters (temperature and humidity) concentrations were analyzed by areas which are urban, sub urban and rural residential areas.

According to Malaysia Ambient Air Quality Guideline, the limit for ozone and nitrogen dioxide concentrations are 100 ppb and 170 ppb respectively for 1-hour averaging period. Hence, for three residential areas, there a no peak concentrations that beyond the limit outlined by the Malaysia Ambient Air Quality Guideline. Hence, the time series plot for 3 days in 24 hours were recorded for the three residential areas.

The ozone concentration of Taman Tun Dr Ismail Jaya was the highest compared to Taman Delima and Taman Kifayah. The emission of nitrogen dioxide concentration in the urban residential was from the heavy vehicles and the industrial activities from the surrounding of the residential area. As shown as in Figure 4.1 below, the trend for the ozone, nitrogen dioxide and volatile organic compound concentrations and meteorological parameters (temperature and humidity) were recorded for Taman Tun Dr Ismail Jaya.

The ozone concentration in Taman Tun Dr Ismail Jaya were completely wash off on the early morning of the second day and the third day because there were presence of rain. The nitrogen dioxide and volatile organic compound were in the atmosphere because of the residential area was heavy with traffic flow. Furthermore, this residential area were also surrounded by other residential and industrial activities.

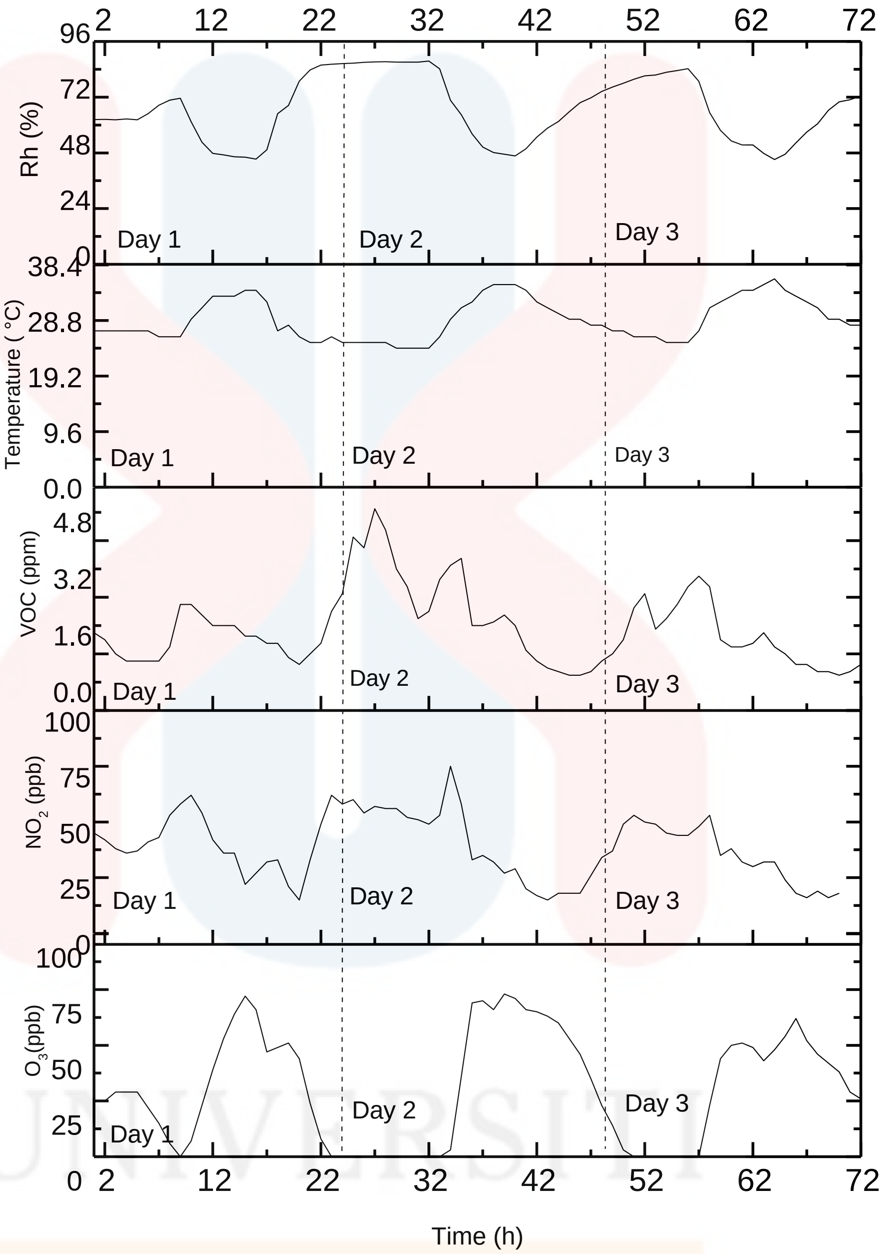

Figure 4.1: Time series analysis of Taman Tun Dr Ismail Jaya (urban residential area)

The ozone, nitrogen dioxide and volatile organic compound concentrations were also being influences by the wind direction and wind speed (Kgabi & Sehloho, 2012). The wind rose of Taman Tun Dr Ismail Jaya was shown in Figure 4.2 below. The wind rose shows the direction of the wind was mostly from ENE for the first day and E for the second and third day with wind speed more than 0.3 m/s. The minimum range of wind speed blowing to the residential area is in the speed of 0.8 until 1.3m/s. The maximum value of the wind speed were on the second and third day in the range of 1.8 until 2.3 m/s. The wind came from the location of pollutant such as vehicles and industrial activities situated nearby. The low wind speed can lead to pile-up of local pollutant instead of high wind speed. High wind speed causing the dispersion of pollutant such as ozone concentration in one area (Sánchez-Ccoyllo, Ynoue, Martins, & de Fátima Andrade, 2006).

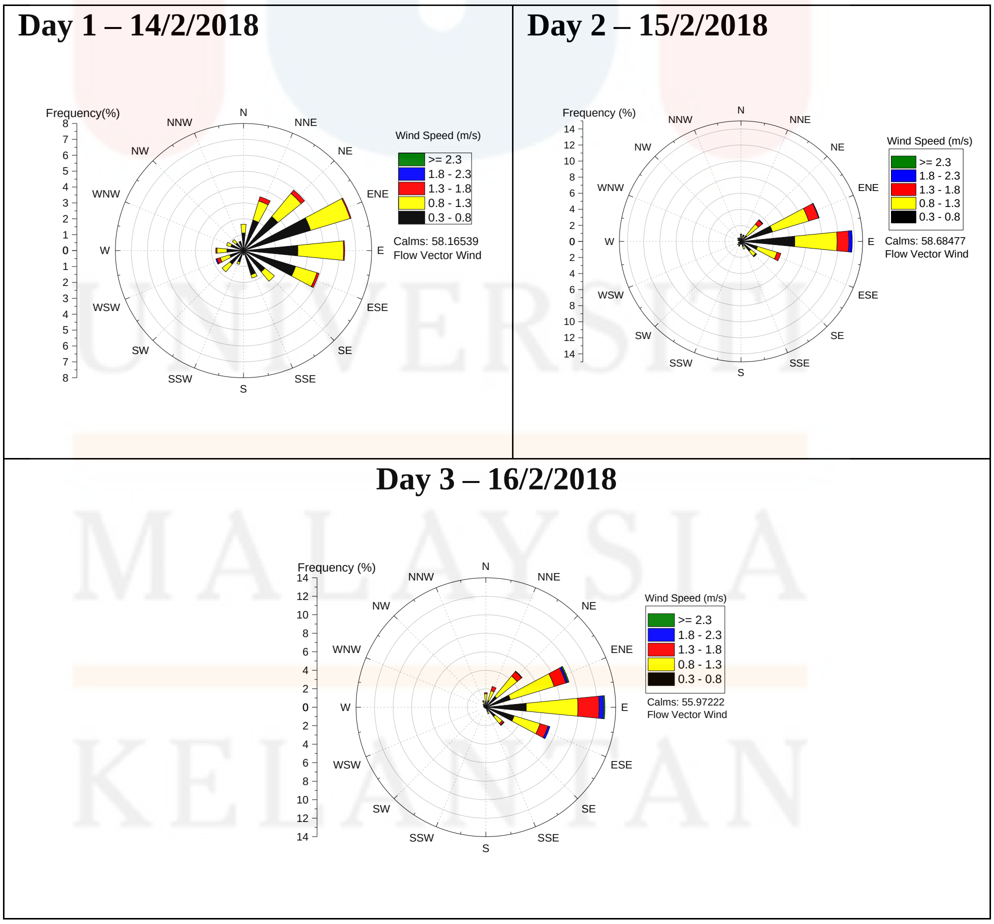

Figure 4.2 Wind rose of urban residential area, Taman Tun Dr Ismail Jaya

Taman Delima, Bakar Arang is a sub urban residential area located in Sungai Petani. As shown in Figure 4.3 below, the trend of ozone, nitrogen dioxide and volatile organic compound concentrations in Taman Delima were recorded in the plot with temperature and humidity in the residential area. The nitrogen dioxide that were being emitted in this residential area were quite high for three days. The monitoring were also being companied by sunny weather and quite windy during the day.

The source of nitrogen dioxide and volatile organic compound emission were from the vehicles and open burning activity of the paddy field Geographically, Taman Delima, Bakar Arang is surrounded with paddy field. The atmosphere also will be affected by the agricultural activity. Hence, the nitrogen dioxide concentration recorded for three days were high.

The fluctuation of ozone concentration of Taman Delima were being observed with its precursors. The presence of high emission of nitrogen dioxide is one of the factor that involved in formation of ozone with the aid of sunlight. The high ozone concentration also being associated with the temperature of the residential area.

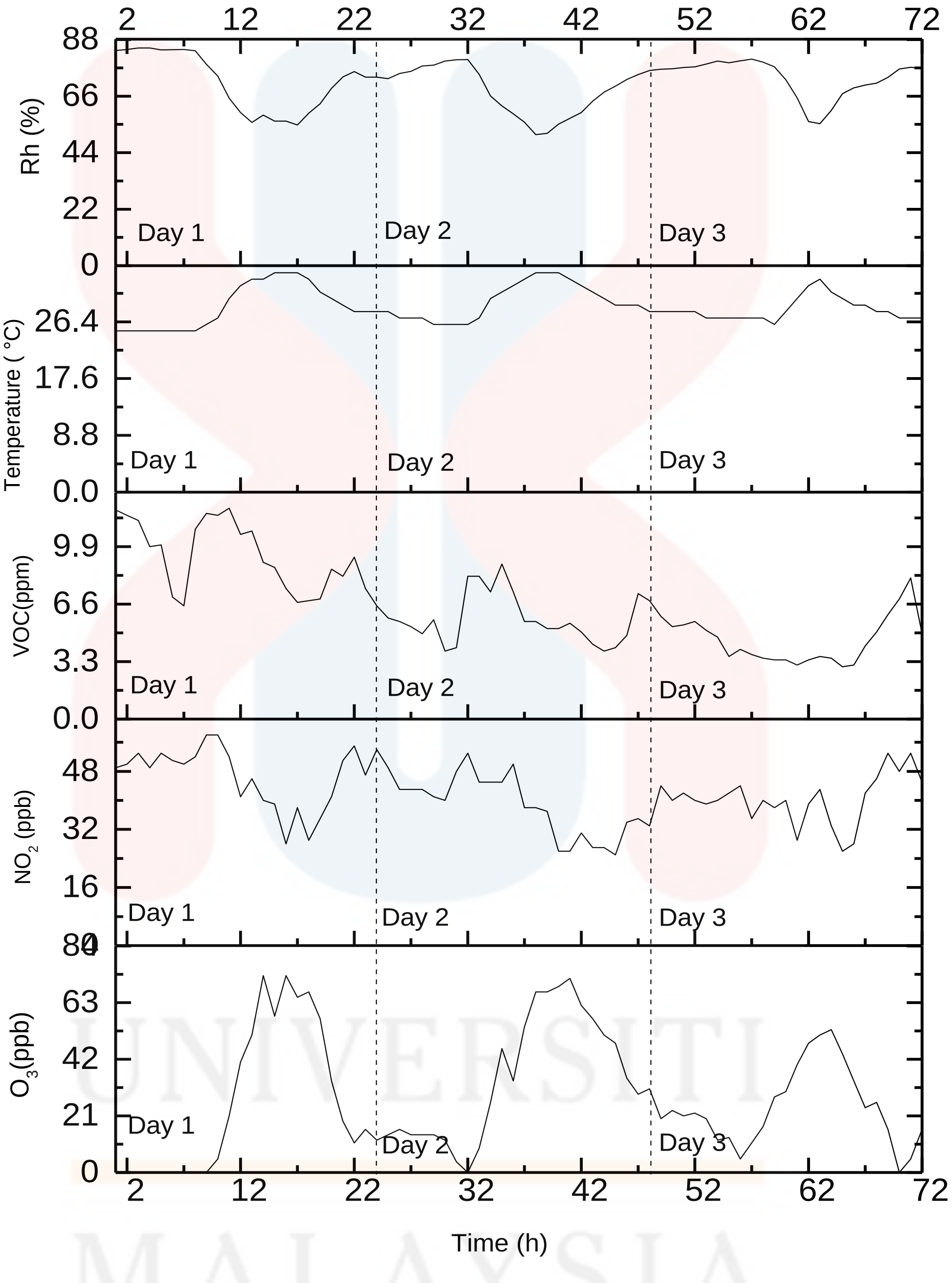

Figure 4.3 Time series analysis of Taman Delima (sub urban residential area)

The wind speed and wind direction of Taman Delima were recorded and analysed in wind rose. Figure 4.4 shown is the wind rose of the sub urban residential area, Taman Delima. The lowest wind speed recorded were 0.3 m/s and the maximum wind speed recorded were 2.3 m/s. The minimum value of the wind speed blowing to Taman Delima is in the range of 1.3 until 1.8 m/s. The average wind speed were quite high in this area due to the Taman Delima area geographically near to the open area which is the paddy field The wind rose as in Figure 4.4 showed that the wind mostly from N to the residential area. The pollutants were mostly from the N direction blowing to the residential area. Source of all pollutant are from the anthropogenic activities in the residential area. Hence, the wind speed act as the medium to the pollutant into the residential area.

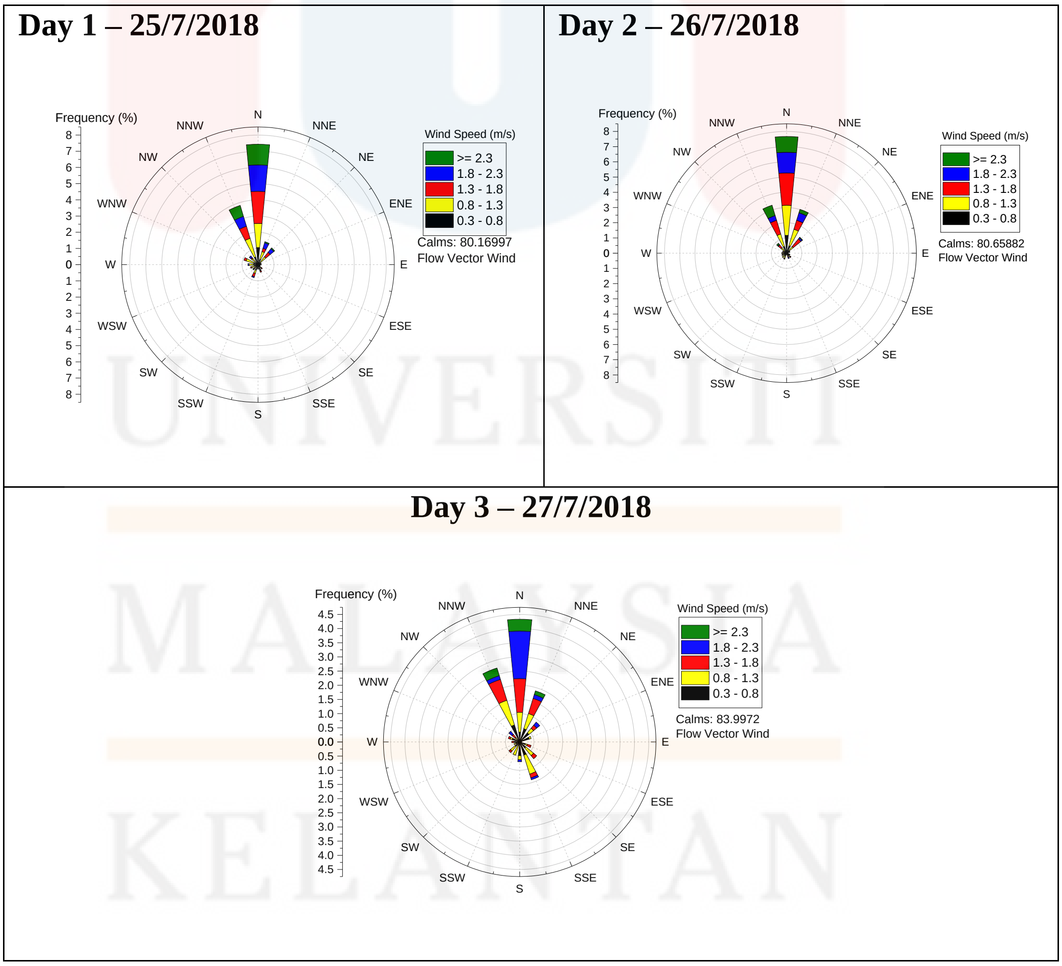

Figure 4.4: Wind rose of sub urban residential area, Taman Delima

Taman Kifayah is the rural residential area located in Jeli, Kelantan. The time series plot of the residential area were being recorded and as shown in Figure 4.5. The ozone concentration in Taman Kifayah show similar trend but with much lower concentration compared to Taman Tun Dr Ismail Jaya and Taman Delima. The ozone concentration started to rise around at the same hours with other areas. During the monitoring, there were presence of light rain during third day of monitoring in the early of morning but in a short period time cause small drop in ozone concentration.

The nitrogen dioxide and volatile organic compound were quite high during nightime because of the emission of the gases to the atmosphere from the factory near the residential area. Nitrogen dioxide and volatile organic compound that being emitted in the atmosphere were one of the factors that influenced the concentration of ozone. The concentration of nitrogen dioxide and volatile organic compound were expected to get impact from the sunlight and water vapour (Sillman, 2002).

The temperature and humidity of Taman Kifayah were also being recorded with ozone concentration and it precursor. Lower temperature will have high humidity and associated with lower ozone concentration (Cardelino et al., 1990). However, according to Sillman (2002), the temperature said have no direct effect on chemistry of nitrogen oxide, and volatile organic compound.

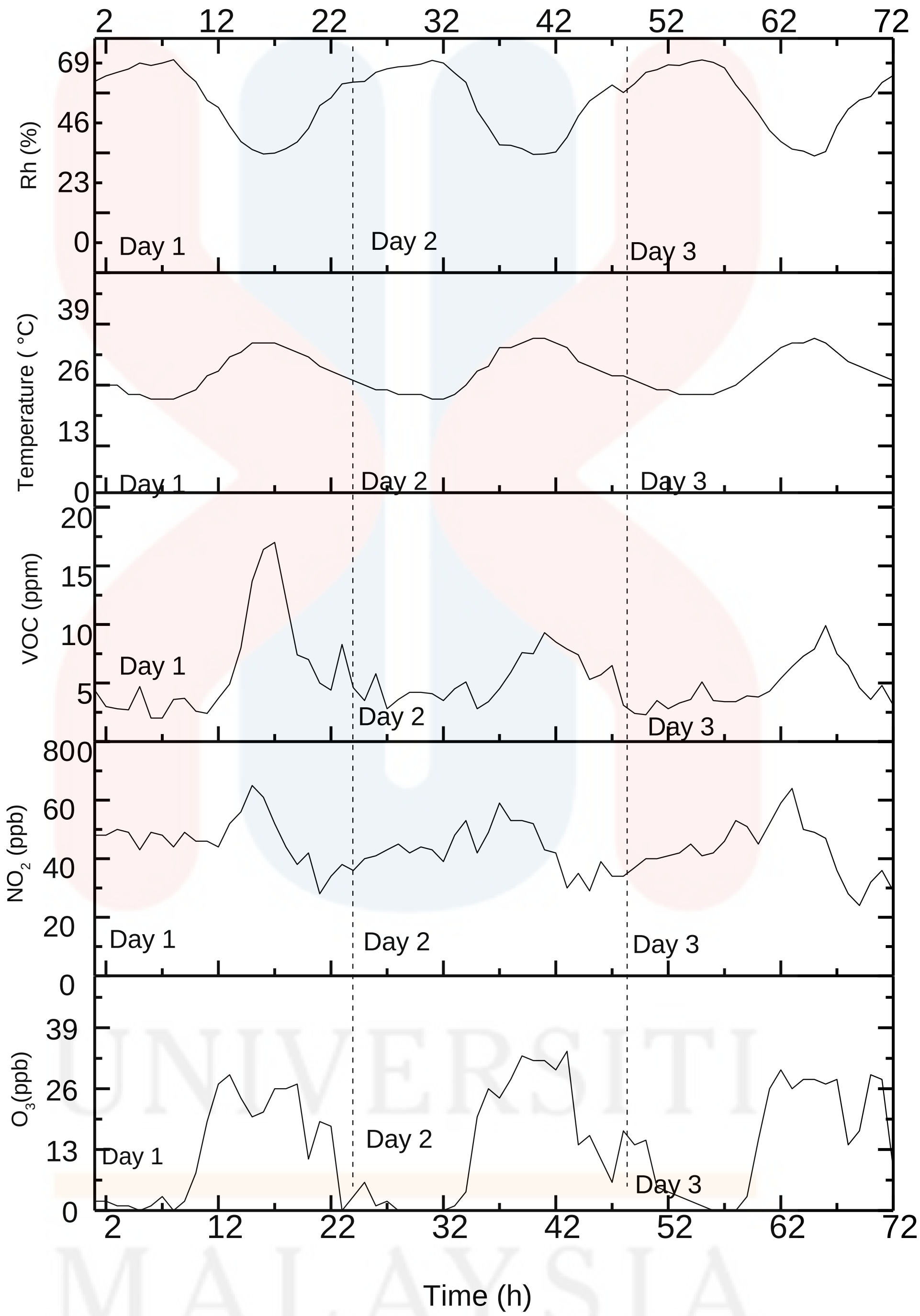

Figure 4.5: Time Series analysis of Taman Kifayah (Rural residential area)

The wind rose of rural residential area, Taman Kifayah were shown in Figure 4.6 above consisting of the wind direction and wind speed. The wind were mostly from ENE direction for first and second day of monitoring. However, the wind were mostly from SW direction on the third day. The wind of the third day were showing dispersion of direction compared to other days. The maximum value of the wind speed from SW direction is in the range of 1.8 to 2.3 m/s but abundantly in the range of 0.8 until 1.3 m/s. In the same direction, the lowest value of wind speed is in the range 0.3 until 0.8 m/s. Overall, the lowest wind speed in Taman Kifayah during monitoring showed in the range of 0.3 until 0.8 m/s. The maximum wind speed in the range of more and equal 2.3 m/s is in the direction of ENE. The pollutants were blowing to the residential area as shown in the wind rose,

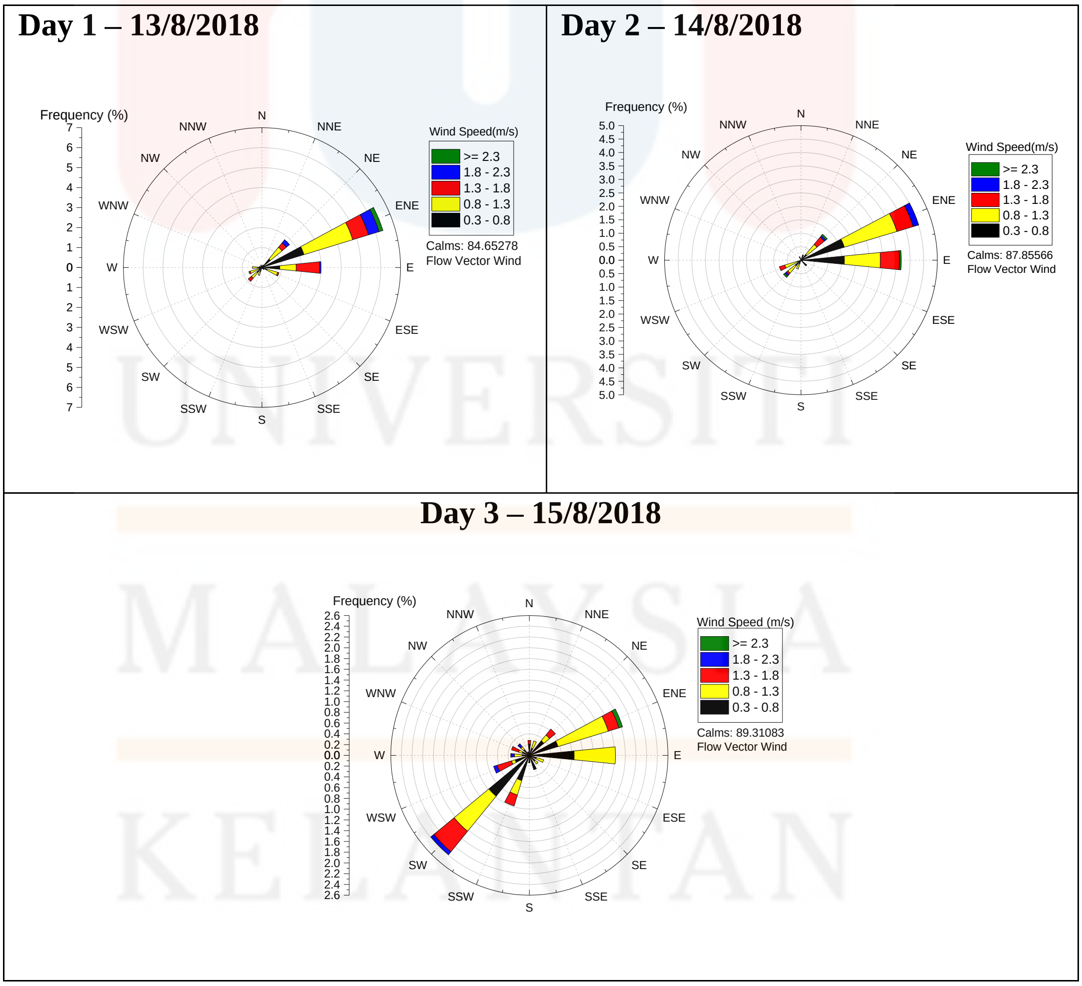

Figure 4.6: Wind rose of rural residential area, Taman Kifayah

4.4 Diurnal Plot of Ozone, Nitrogen Dioxide, Volatile Organic Compound Concentrations, Temperature and Humidity

The composite diurnal being plot for the three residential areas, Taman Tun Dr Ismail Jaya (urban), Taman Delima (sub urban) and Taman Kifayah (rural) in average of three days in 24 hours. The composite diurnal plot of Taman Tun Dr Ismail Jaya were being recorded in Figure 4.7.

The ozone concentration of Taman Tun Dr Ismail Jaya started to rise around 10 a.m. and at its peak around 3 p.m. The ozone started to intercept with nitrogen dioxide around 11 a.m. to 1200 a.m. However, the ozone concentration started to fall around 1700 hours. The concentration of ozone started to fall in the evening and at night. When ozone concentration started to rise, the nitrogen dioxide concentration began to fall. The decrease of the ozone concentration was because of the less emission of nitrogen dioxide from the vehicles of the traffic.

The temperature of Taman Tun Dr Ismail Jaya was in the range of 25 °C until 32 °C. The temperature were associated with humidity of the area. Low humidity always associated with high temperature. The peak of the temperature during noon make the ozone concentration at its peak. The photochemical reaction increases with high temperature that influences the formation of ozone (Jasaitis, Vasiliauskiene, Chadyšiene, & Pečiuliene, 2016).

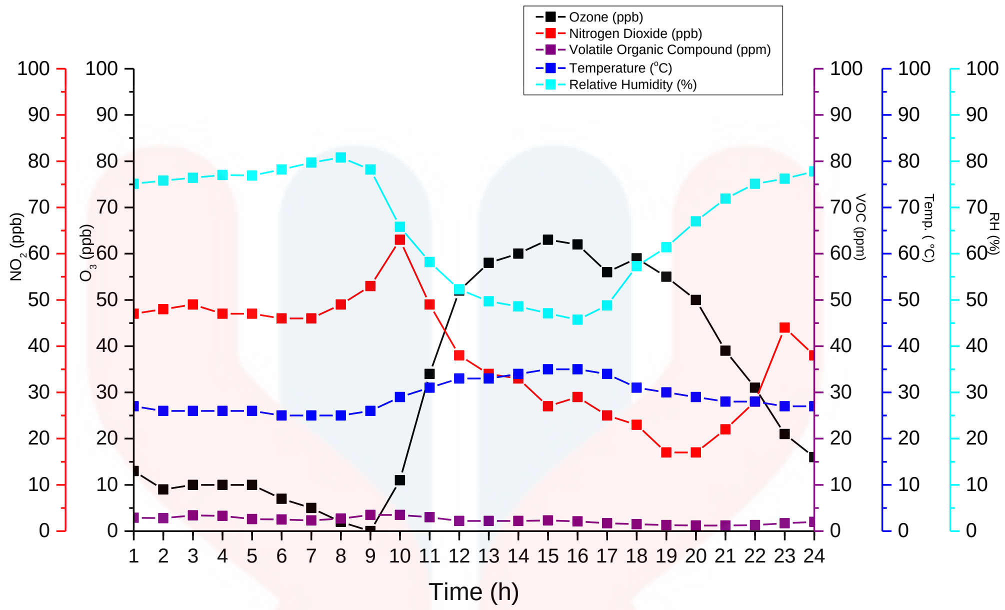

Figure 4.7: Composite diurnal plot of urban residential area, Taman Tun Dr Ismail Jaya

Sub urban residential area, Taman Delima is one of residential area that have quite heavy flow of traffic especially during noon and in the evening. The area also near the paddy field which is one of the agriculture activity of the residential area. The ozone concentration started to rise at 0900 hours and its peak at 1600 hours as shown in Figure 4.8 below. The peak time of ozone concentration quite late due to the presence of rain during the second day of monitoring.

The nitrogen dioxide and volatile organic compound concentration of the area were mainly from the open burning of the paddy field. Since the area is near the paddy field, the agriculture activity will become one of the factor that impact the concentration. Taman Delima which is located in Kedah geographically an open area and have quite high temperature annually. The wind speed were also high compared to the other two residential area due to its geography.

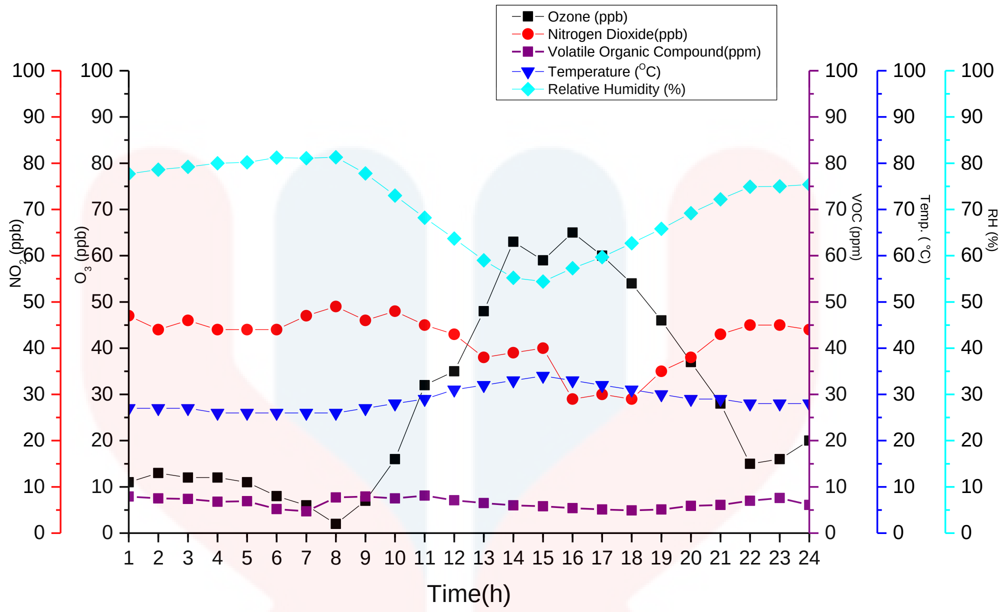

Figure 4.8: Composite diurnal plot of suburban residential area, Taman Delima

Figure 4.9 below shown the composite diurnal plot of Taman Kifayah which is the rural residential area. Taman Kifayah has the lowest ozone concentration compared to the other two residential areas. The ozone concentration start to rise around 9 a.m. and its peak at 12 a.m. The ozone concentration also start to decrease at 1800 hours. The nitrogen dioxide concentration is much higher in reading compared to the ozone concentration. For this residential area, there is no interception between the ozone concentration and nitrogen dioxide concentration which means both concentrations were quite low in this area.

The emission of nitrogen dioxide were much lower than the other two places because this area has less traffic low. However, the traffic flow nearby this residential area will get heavy during school vacation since it’s the main road that connects the north and east part of peninsula Malaysia. The formation of the ozone in this area also being influenced by the temperature and humidity.

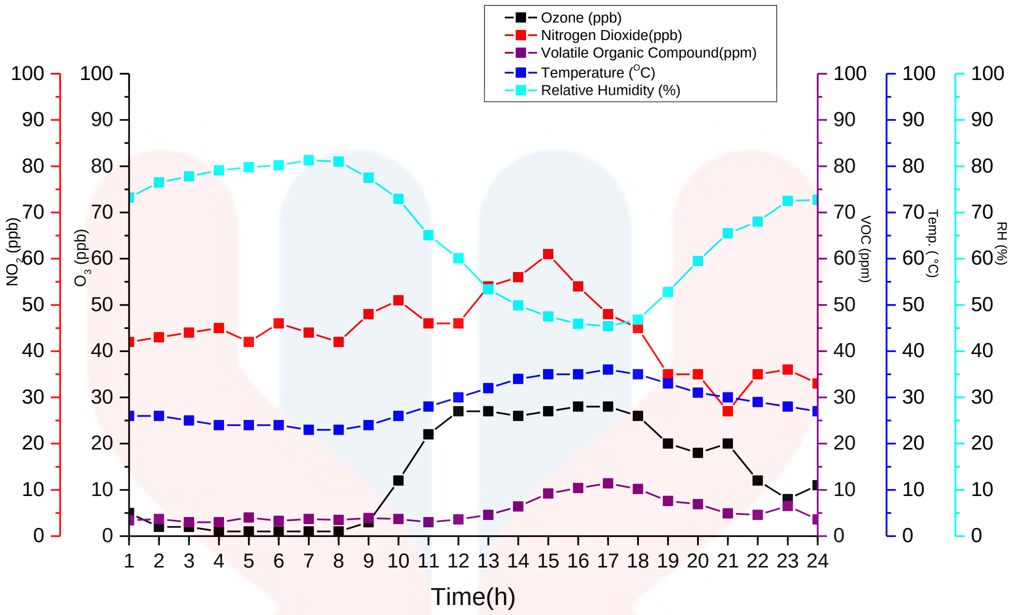

Figure 4.9: Composite diurnal plot of rural residential area, Taman Kifayah

4.5 Comparison Ground Level Ozone of the Residential Areas

One way 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. This statistic test give the information on the significance difference of the ozone concentration of the three areas. Result of the one way ANOVA and the multiple comparison between the residential areas were showed in the Table 4.4 and Table 4.5.

Table 4.4 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.

Table 4.4: 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 4.5: Multiple Comparison O_3 concentration of three residential areas

	(I) Station	(J) Station	*P-value*	95% Confidence Interval	
				Lower Bound	Upper Bound
Tukey HSD	Bakar Arang	Shah Alam	0.04	-16.18	-.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

The comparison between the residential areas were shown in Table 4.5. 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 signifance difference in the ozone concentration among the residential areas. The p-value for comparing Taman Delima,Bakar Arang and Taman 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, its also indicate that there were significance between the residential areas.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 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 ozone concentration of the three residential areas were under safe and not over the permissible value recommended by the Recommended Malaysian Ambient Air Quality Guideline. The highest mean of ozone concentration were recorded on second day in Bakar Arang (35.2 ppb) due to open burning of paddy field while the lowest mean were recorded on the first day (12.1 ppb) in Jeli. However, ozone concentration in Shah Alam was the highest averagely.

The ozone, nitrogen dioxide, volatile organic compoud and meteorological parameters in duration of 72 hours for three different residential areas were being illustrated in the time series plot. The continuos cycle for them can be seen through this plot. The diurnal patterns of the ozone, nitrogen dioxide, volatile organic compoud and meteorological parameters showed the trend of 24 hours in the three different places. From the diurnal patterns, the peak time of the ozone concentration for the residential areas usually at 12 p.m. or 2 p.m. in the sunny weather condition and less cloud cover. The ozone precursors diurnal trend that influences the ozone concentration were also showed in the diurnal trend plot. Wind speed and wind direction were the meteorological factors that been observed in this study. Hence, wind rose showed the wind speed and its direction into the residential areas. Wind that present in the atmosphere influenced the presence of pollutants in one area. However, 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 are significance difference. This study emphasises that different residential areas, Taman Tun Dr. Ismail Jaya in Shah Alam, Taman Delima in Bakar Arang and Taman Kifayah in Jeli have different concentration of ozone with the meteorological factors and differ in the sources of pollutants that influencing the ozone concentration.

5.2 Recommendations

This study is the comparative study of the ground level ozone in three different residential areas consist of the urban, sub urban and rural areas. This study suggest to investigate the concentration of ozone precursors and the meteorological factors that influence the formation of the ozone. It also been said that the meteorological factors such as the wind speed and wind direction that blowing to the area were also influencing the ozone formation. More technological tools that are more precise and accurate which can cover all the data is suggested to use for the study. This is because there is missing data due to the failure of the monitoring tool.

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