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The Exploration of the Changes In Surface Ozone by Region and Season

(Variasi Permukaan Ozom Mengikut Kawasan dan Musim)

Firdaus Mohamad Hamzah [a*,b], Alyaa Najihah Ishak[c], Nuryazmin Ahmat Zainuri [c], Norshariani Abd Rahman[d], Mohd Khairul Amri Kamarudin [e], Mohd Saifullah Rusiman [f] & Siti Hasliza Ahmad Rusmili[c]

[a]*Department of Engineering Education, Faculty of Engineering & Built Environment, Universiti Kebangsaan, Malaysia*
[b]*Centre for Engineering Education Research, Faculty of Engineering & Built Environment, Universiti Kebangsaan Malaysia*
[c]*Department of Civil Engineering Faculty of Engineering & Built Environment, Universiti Kebangsaan Malaysia, Malaysia*
[d]*Institute of Islam Hadhari, Universiti Kebangsaan Malaysia, Malaysia*
[e]*Faculty of Applied Social Sciences, Universiti Sultan Zainal Abidin, Malaysia*
[f]*Faculty of Applied Sciences and Technology, Universiti Tun Hussien Onn Malaysia*

**Corresponding author: fir@ukm.edu.my*

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ABSTRACT

The growth of air pollution as a serious concern throughout the country is influenced by several causes sourcing from transportation, combustion, and industrialization. These factors reduced the air quality which harms society, animals, and plants' well-being. Surface ozone is one of the main causes of air pollution in developing areas around the world. Analysis of surface ozone by area and season variations increased during summer were associated with meteorological parameters such as atmospheric temperature and humidity, meanwhile, the concentration of surface ozone is low during the northeast monsoon season. In addition, the concentration of surface ozone also increases when there are other environmental influences such as the release of pollutants from anthropogenic activity. Therefore, a study will be carried out to identify the variation of surface ozone concentrations by region and monsoon season in peninsular Malaysia, especially in the northern, eastern, and western zones, to identify the highest duration for daily ozone concentration (O_3) and to study the relationship between the monthly and annual surface ozone concentrations with meteorological parameters. The results in this study can be used to identify air quality and address the problem of air pollution so that human health and the environment are preserved by using the method of boxplot and line graph obtained from descriptive statistics.

Keywords: Surface ozone; temperature; humidity; monsoon seasons

ABSTRAK

Kemunculan pencemaran udara sebagai masalah utama di seluruh negara dipengaruhi oleh beberapa punca utama iaitu pengangkutan, pembakaran serta perindustrian. Pengaruh tersebut telah mengurangkan taraf kualiti udara yang akan memudaratkan kesejahteraan masyarakat, haiwan dan tumbuh-tumbuhan. Ozon permukaan, merupakan salah satu punca utama pencemaran udara di kawasan pembangunan seluruh dunia. Analisis ozon permukaan mengikut kawasan dan variasi musim meningkat semasa musim panas dikaitkan dengan parameter meteorologi seperti suhu atmosfera dan kelembapan, manakala kepekatan ozon permukaan adalah rendah semasa musim tengkujuh. Selain itu, kepekatan ozon permukaan juga boleh meningkat apabila terdapat pengaruh persekitaran yang lain seperti pembebasan bahan pencemar dari aktiviti antropogenik. Oleh itu, kajian ini akan dilaksanakan bagi mengenal pasti variasi kepekatan ozon permukaan mengikut kawasan dan musim monsun di semenanjung Malaysia khususnya di kawasan utara, timur dan barat, mengenal pasti tempoh bagi kepekatan harian ozon (O_3) yang paling tinggi dan mengkaji hubungan di antara kepekatan bulanan dan tahunan ozon permukaan dengan parameter meteorologi. Hasil kajian ini boleh digunakan bagi mengenal pasti kualiti udara dan menangani masalah pencemaran udara supaya kesihatan manusia dan alam sekitar terpelihara dengan menggunakan kaedah plot kotak dan graf garisan yang diperoleh dari statistik deskriptif.

Kata kunci: Ozon permukaan; suhu; kelembapan; musim monsun

INTRODUCTION

The ozone layer is a layer of gas that absorbs the ultraviolet (UV) rays emitted by the sun. The importance of the ozone layer is to preserve and protect humans and the environment on earth from the adverse effects of sunlight (UV). Increased ultrasound rays can form skin cancer, genetic damage to humans, and threaten animal and plant species. Ozone is an organic compound that contains each of its molecules three oxygen atoms. It exists in the layer between the stratosphere and the troposphere ozone layer serves as the earth's protector from sunlight or UV. Stratospheric ozone is considered beneficial for humans and other lives as it forms as a protector to absorb harmful ultrasound (UV)-B rays (Zhang, Wei & Fang 2019). Exposure to higher sunlight can lead to skin cancer, cataracts of the eye as well as immunization system (Rajab, MatJafri & Lim 2013). While troposphere ozone is a reactive gas that negatively affects humans, climate, and plants (Derwent 2020). This air is a pollutant for three basic processes namely the photochemical production process through the reaction between hydrocarbons and nitrogen oxides (NO), vertical air transport from stratospheric ozone to the troposphere, and transport horizontally because ozone-carrying winds (O_3) are produced in different areas (Pires & Martins 2011). Ozone formation is a different process in terms of time and according to the circumstances of an area. Ozone is produced in various chemical reactions, but the first mechanism is the absorption of ultraviolet radiation energy (UV) from the sun and displacement in the atmosphere (Carro-Calvo et al. 2017). Ozone (O_3) will form when the oxygen gas (O_2) acts to absorb sunlight (UV) at a wave distance of 242 nanometers and is broken down in the removal of the chemical-light response from the sun by a wave distance of more than 290 nanometers. Ozone is also a unique pollutant as it is not released into the air directly and is a result of the complex reaction of chemicals in the atmosphere (Rajab & Lim 2013). This issue was chosen to determine the air quality and ozone behavior on the surface because high production of surface ozone will reduce the quality of air which brings negative impacts on the human respiratory systems and defects to the growth of plants. In addition, ozone is a secondary (Sanjay Rajagopalan, MD,a,b Sadeer G. Al-Kindi, MD,a Robert D. Brook 2018) air pollution as it is not directly released but formed in the troposphere due to chemical reactions between sunlight and pollutants such as particulate matter (PM10) (Wang, Cohan & Xu 2020).

Surface ozone (O_3) is a secondary pollutant as surface ozone is formed from the reaction of other pollutant gas particles. The process of ozone gas formation depends on natural factors and the amount of gas accumulated as a result of human activity on earth. The natural production of ozone molecules is the result of the absorption of ultraviolet rays (UV). High-concentration ozone gas is not only limited to the urban environment but also affects remote areas of the region (Bachtiar et al. 2015). Apart from the surrounding area, the concentration of ozone gas can also be affected by the state of atmospheric composition and the influence of the alteration of the tropospheric ozone and stratospheric ozone. Inhaled ozone can cause various health problems such as chest pain, cough, and worsening congestion are bronchitis, and asthma. Surface ozone can also reduce lung function. Besides adversely affecting humans, ozone on the surface can also negatively impact plants and ecosystems. Among its effects is the difficulty for plants to produce food and store food, these plants are exposed to the risk of certain diseases, attacks of destructive insects, and competition with other plants. The emergence of crops in recreational areas or national parks is also defendant because ozone pollutants (O_3) reduce forest growth and crop yields from various species in the ecosystem. Pollutants that damage crops other than ozone (O_3) are other hydrocarbon chemicals. These pollutants will seep into plants during the process of food production and food storage, through stomata space. These materials will also destroy leaf cells when the material is in the leaves at once the rate of photosynthesis is less occurring and can turn off this plant. Indirectly, the safety of land or aquatic animals is also threatened when pollutants such as ozone (O_3) are in plants. Animals also depend on plants to obtain food for survival. Humans who have diseases in pneumonia, children, senior citizens, and people who are exposed to air pollution due to outdoor activities can be affected by harmful surface ozone (Amato et al. 2010). Prolonged exposure to surface ozone according to scientific studies can cause various problems such as headaches, respiratory tract problems, difficulty breathing either during outdoor activities or exercise, skin inflammation, and worsen asthma (Bachtiar et al. 2015). Background area have higher ozone levels than urban. Surface ozone has a lot of geographical and temporal heterogeneity (Yeo et al. 2021) At different time scales, many relevant causes influenced ozone fluctuation (Ma et al. 2021).

Malaysia was hit by the southwestern monsoon wind season which is the wind blowing from the Indian Ocean ("MyGOV - Maklumat Malaysia | Iklim" 2017). At the moment, Malaysia is experiencing very hot weather and less rain distribution from May to September. When a country is hit by summer and low humidity, forest burning and haze are likely to occur in some areas. This condition can make air quality less clean and harmful to the health of the inhabitants of the earth. Low air quality is defined as the maximum surface ozone concentration. Meanwhile, the northeast monsoon season hit in early November to March, when Malaysia will receive a high rainfall distribution in the east coast states such as East Johor, Terengganu, Pahang, and Kelantan. Areas that regularly receive rainfall distribution can cause flooding to occur especially in low areas (Firdaus Mohamad Hamzah 2017).

The challenge is that air pollution will be more likely to occur in the environment than other types of pollution, this is because every active activity will affect air content (Haliza Abd Rahman & Rapeah Suppian 2013). Apart from suspended organic particles, even surface-released toxic gases increase the percentage of air pollution frequency.

Among the particles that are suspended in the air are carbon, soil dust, or (PM10), for harmful gases, consist of nitrogen dioxide (NO_2), carbon monoxide (CO), sulfur dioxide (SO_2), and ozone (O_3). The air pollution that hit resulted in decreased air quality and an increase in surface ozone in the atmosphere. For instance, presence of carbon monoxide (CO) released from vehicles becomes a strong correlation with surface ozone (Awang et al. 2016). But at the same time, the green-house phenomenon is closely related to global warming (Ying, Fook & Glasow 2013) and potential for global warming is increasing in the atmosphere due to the increase in ozone on the surface as a result of the reaction from the pollution gases generated in the atmosphere. Previous studies have shown that ozone pollutants (O_3) are more widely studied (Ahmadi & John 2015) and evaluated, but their value is uncertain. The results of this study can be used to identify air quality and address the problem of air pollution so that human health and the environment are preserved (Napi et al. 2020).

Therefore, this study aims to identify the monthly concentration variation of surface ozone by region and monsoon season in Peninsular Malaysia. In addition, the objectives to be achieved is to identify the duration of the highest daily concentration of ozone and to investigate the relationship between the monthly and annual concentrations of surface ozone with meteorology parameters.

METHODOLOGY

This section discusses the method adopted in this study. The first subsection discusses site selection followed by a section discussing sample and data collection and data analysis. To achieve the objectives of the study, the area of study should be chosen based on human activities and land use (Sonkaew & Macatangay 2019). Based on the Air Pollution Index in Malaysia (APIMS) reading ("APIMS" n.d.), in Sungai Petani, Kedah is the highest ever recorded API reading in Malaysia in 2013 ("Bakar Arang, Sg. Petani catat jerebu tertinggi hari ini | Astro Awani" 2013). In addition, the press statement (Karim 2019) stated that a place in Klang and Indera Mahkota Kuantan had recorded an unhealthy API reading in 2019. Therefore, these areas were selected based on the API reading record in Malaysia. Furthermore, the selection of monitoring stations for the north, west, and east areas are due to pollution factors, locations nearby ports and industries, even highly populated areas

SITE SELECTION

This research study was conducted in Peninsular Malaysia involving the northeast monsoon wind zone and the southwest monsoon wind that shown in Figure 1. The selected zone in Peninsular Malaysia in this study are Kedah, Selangor, and Pahang (Figure 2). This study raises the issue of surface ozone scenario and air quality in Malaysia and will also take into account the factors of air quality, surface ozone concentration, and some air quality parameters in the study area. This study focuses on areas with monsoon seasons such as those in the west and east. This is because Malaysia is hot and humid throughout the year. Several types of monsoon seasons hit areas in peninsular Malaysia, to conduct this study, the monsoon season involved the northeast monsoon and southwest monsoon wind.

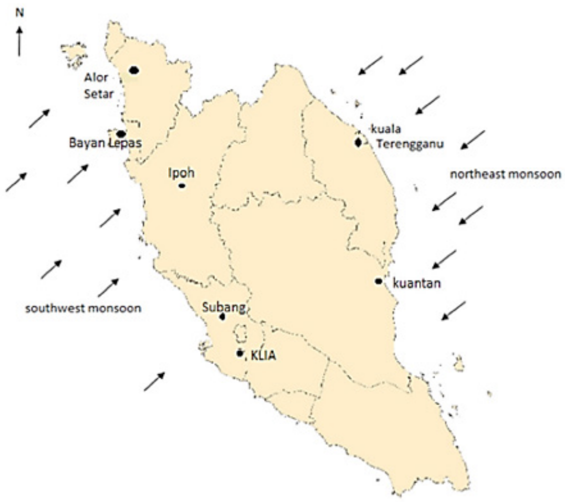


FIGURE 1. Location of daily wind direction
Source: Satari et al. (2015)

FIGURE 2. Location of automatic air quality monitoring stations

Figure 2 shows three automatic air quality monitoring stations for the northern, eastern, and western zones. The data for the three selected areas will be used and analyzed in this study as it is a highly-populated area, a port area, an industrial area, and has even recorded the lowest air quality in Malaysia. The coordinates of the air quality monitoring station for each area are set out in Table 1. The data for surface ozone concentration (O_3) and temperature is obtained from the Department of Environment (DOE) every month and meteorological parameters are taken at four automated air quality monitoring stations located in Klang Selangor, Sungai Petani Kedah, and Indera Mahkota Pahang. The data used is from 2010 to 2018. Through an analysis conducted over 9 years (2010 to 2018) in selected areas to identify the highest amount of surface ozone concentrations can be recorded.

TABLE 1. Location of Air Quality Monitoring Stations

Zones		
North	Station Name	Sek. Keb. Tunku Ismail, Bakar Arang, Sungai Petani
	Station	CA0017
	Longitude	N5°37’51.1”
	Latitude	E100°28’09.1”
East	Station Name	Sek. Keb. Indera Mahkota, Kuantan
	Station	CA0014
	Longitude	N3°49’04.5”
	Latitude	E103°17’52.4”
West	Station Name	Sek. Men. (P) Raja Zarina, Kelang
	Station	CA0011
	Longitude	N3°00’29.5”
	Latitude	E101°24’28.5”

DATA ANALYSIS METHODS

The data obtained from the station monitoring will be analyzed to obtain the results of the study on surface ozone and air quality by area and monsoon season. Statistical Package for the Social Sciences (SPSS) software will be used to analyze the data. In each station, there is some missing ozone concentration data. For the northern region, the missing data is 5311, the western region recorded the missing data of 6058 and the missing data for the eastern region was 9387. These missing data mostly occur at the same time and on the same day. Then, the missing data will be replaced with the previous data to make it easier to plot the graph. The missing data that has been cleared through computerized software SPSS and Excel will be collected to form pivot tables so that average of ozone concentration and meteorological parameters can be identified. The graphs to be plotted in this study are boxplot graphs and line graphs to identify the highest concentration of surface ozone.

RESULT AND DISCUSSION

This data is about the variation in the concentration of surface ozone in peninsular Malaysia according to the two monsoon seasons that hit the northern, eastern, and western regions.

TABLE 2. Descriptive statistics for three regions in Peninsular Malaysia

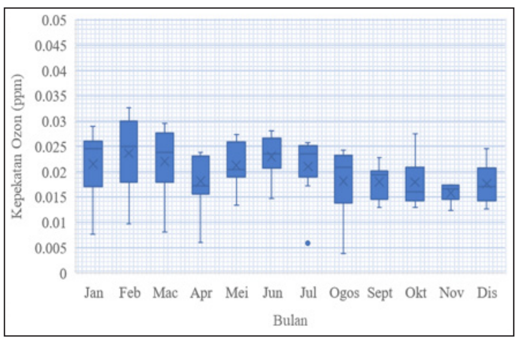
Location	Parameter	Min	Max	Mean	Stand. Dev.
Sungai Petani	Ozone conc.	.0001	.1170	.02008	.016652
	Temperature	-39.40	40.70	27.732	3.55469
	Humidity	1.40	99.40	75.139	15.5863
Klang	Ozone conc.	.0001	.1410	.01929	.017931
	Temperature	16.90	37.60	28.578	2.74946
	Humidity	1.30	99.70	72.315	13.5788
Indera Mahkota Pahang	Ozone conc.	.0001	.1350	.01830	.013496
	Temperature	-40.00	38.10	27.006	3.24667
	Humidity	41.40	100.10	88.804	11.2547

Table 2 shows descriptive statistics using SPSS software for each air quality monitoring station in the north, east and west zones. As for Sungai Petani, the area represents the northern zone, Klang represents the western zone and Indera Mahkota Kuantan from the eastern zone. Temperature and humidity are meteorological parameters related to the concentration of surface ozone used in this study. High temperatures will cause the production of high levels of surface ozone (Saini, Taneja & Singh 2017).

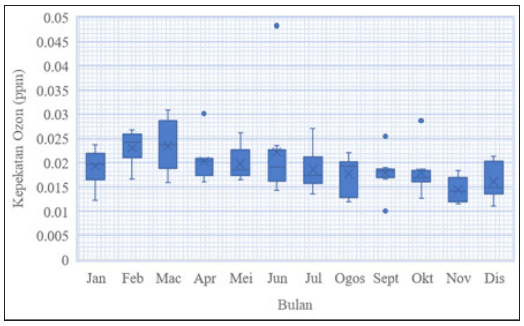
VARIATION OF OZONE CONCENTRATION EACH STATION

From the descriptive analysis shown in Table 2, the monthly average for surface ozone concentration at Sungai Petani station, Kedah was 0.0201 ppm, in Kuantan, Pahang was 0.0183 ppm and in Klang, Selangor was 0.0193 ppm. The average for stations in Kedah, Pahang, and Selangor was approximately the same for 9 years recorded using calculations through Microsoft Excel.

(a) Southwest Monsoon Season

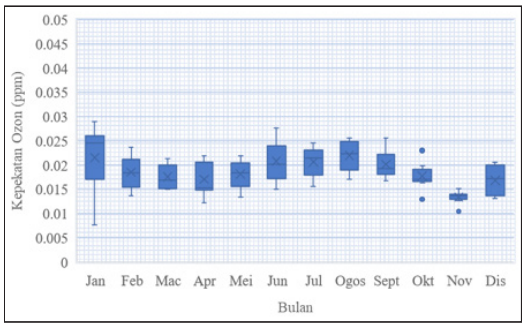


i. North



ii. West

(b) Northeast Monsoon Season



iii. East

FIGURE 3. Boxplot of monthly average surface ozone concentration data by region and monsoon season

Figure 3 shows the boxplot of monthly average surface ozone concentration (O_3) of stations in the north, east and west zones of Peninsular Malaysia from 2010 to 2018.

For the northern zone of Sungai Petani, Kedah (northern zone), the highest average of surface ozone concentration reading for 9 years was 0.117 ppm in October. Surface ozone concentration increased from April to June and it began to decrease after July to November. But the reading began to surge again when in January and February, however, surface ozone concentrations decreased more after March.

Overall observations from Table 2 and Figure 3, the highest reading of surface ozone (O_3) concentration was from April to August with the highest reading of 0.141 ppm in Klang, Selangor in July. After August, the average number of surface ozone concentrations decreases until the beginning of the year. This indicates that Klang, Selangor (western zone) is the most polluted area compared to the northern and eastern regions. The reading of surface ozone concentrations is high from April to June and decreases after July until the end of the year.

The air quality of monitoring station located in the eastern zone of Kuantan, Pahang is the highest population of 0.5 million (Department of Statistic Malaysia 2020) and close to various industries. The highest surface ozone concentration in Kuantan was 0.0135 ppm in July. Surface ozone readings increased from April to August. However, the ozone concentration readings decreased after September.

The level of ozone concentration (O_3) recorded was high and increased frequently between April and August. This proves the increase in the concentration of surface ozone occurs when the southwest monsoon season hits in Malaysia especially in the northern and western regions with the monthly average reading of the maximum surface ozone concentration apart from the eastern regions. Meanwhile, the reading of surface ozone (O_3) decreases when the northeast monsoon season or more commonly known as monsoon season around November to March hits Malaysia, especially on the east coast. The surface ozone concentration reading for the east zones is currently low compared to the north and west zones.

Therefore, variations in surface ozone concentrations by region and monsoon season greatly affect air quality recorded at automated air quality monitoring stations in Malaysia. During southwest monsoon season approached, the surface ozone concentration recorded is high, while the recorded concentration of surface ozone is low during northeast monsoon season. Based on Figure 3 below show the monthly surface ozone concentration for a) southwest monsoon season and b) northeast monsoon wind for three stations in Peninsular Malaysia in north, west, and east zones.

HOURLY SURFACE OZONE CONCENTRATION

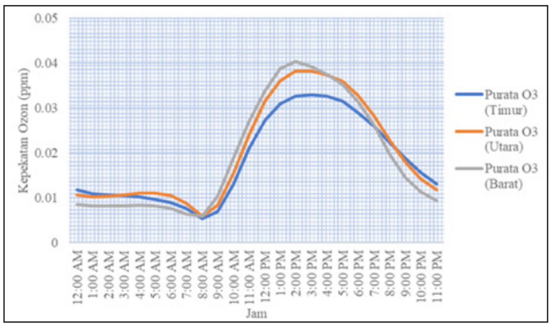


FIGURE 4. Line graph of hourly average surface ozone concentration (O_3) by region

Figure 4 shows the daily concentration of surface ozone (O_3) for each monitoring station in the north, east, and west. In this chapter, we will discuss the value of air quality parameters for example ozone (O_3) surfaces per hour to identify the highest surface ozone emissions. Overall, the average hourly surface ozone increased sharply between 12:00 AM to 4:00 PM at the peak (Mohamed Noor, Mohamad Hasim & Yusof 2018). The presence of sunlight and reaction with pollutants present in the air will produce surface ozone (O_3). The ability of pollutants produced from anthropogenic activities and other vehicle smoke is a contributing factor to the increase in ozone. Air pollution mainly in urban areas is 98% of motor vehicles or land transport (Yew & Undang-undang 2017). In various reactions in the air, ozone will be destroyed throughout the day and night but formed only during the day and the hot weather will increase the surface ozone concentration.

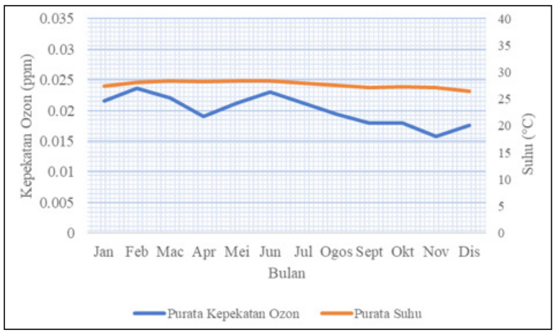
Based on Figure 4, the hourly average concentration of surface ozone in the northern zone increased from 9:00 AM to 3:00 PM. The highest reading recorded was 0.0375 ppm at 2:00 PM and 3:00 PM. However, the reading of surface ozone concentration began to decrease in the afternoon. In the eastern region, a high reading of surface ozone concentration was recorded from 10:00 AM to 4:00 PM with the highest reading of 0.033 ppm at 2:00 PM to 4:00 PM. The value of surface ozone concentration in the eastern zone is lower than the north zone. The average reading of surface ozone concentration in the western zone increased from 10:00 AM to 2:00 PM with the highest average of 0.04 ppm which is the highest reading compared to the north and east zones. The average reading of surface ozone starts to decrease from 3:00 PM to late at night.

The hourly average surface ozone concentration is higher at noon or peak hour. In Figure 4, the areas affected by the southwest monsoon season recorded the highest hourly concentration of surface ozone compared to the areas affected by the northeast monsoon season. The increase and decrease in the surface ozone concentration (O_3) are associated with the availability of photochemical processes that derive energy from sunlight (Ma et al. 2016). Therefore, the intensity of sunlight is high at noon when responding with other pollutants will result in an increase in the concentration of surface ozone (O_3). Meanwhile, during the night to early morning, the average concentration of surface ozone decreases due to the absence of sunlight, therefore, photochemical processes cannot be carried out at this time (Mohamed Noor, Mohamad Hasim & Yusof 2018).

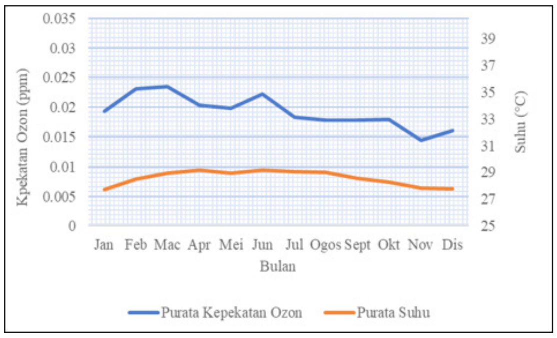
RELATIONSHIP BETWEEN OZONE CONCENTRATION AND METEOROLOGICAL PARAMETERS

Other factors that could worsen the pollution situation are the monsoon seasons and the El-Nino phenomenon. This phenomenon is prolonged and dry weather especially when the southwestern monsoon winds hit Malaysia causing a decrease in air quality as there are hazardous mixed materials affected by meteorological factors such as temperature (Molina et al. 2017). Ozone concentration and meteorological parameters are the sources of pollution based on Ili, Popovi & Ne (2020) studies. According to the study of surface ozone concentration (O_3) data, it was found that all three stations showed varying patterns with seasonal variations in a time series. Within a year, the concentration pattern of surface ozone by region and monsoon season can be shown with a complete-time series and the next year will repeat.

(a) Southwest Monsoon Season

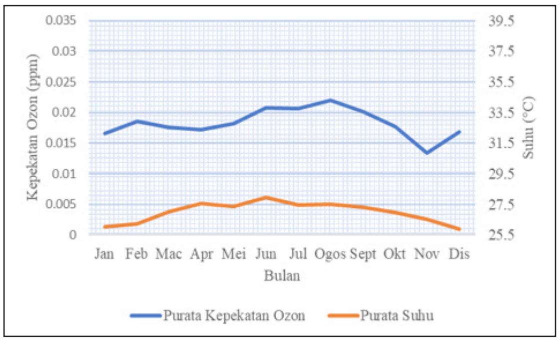


i. North



ii. West

(b) Northeast Monsoon Season



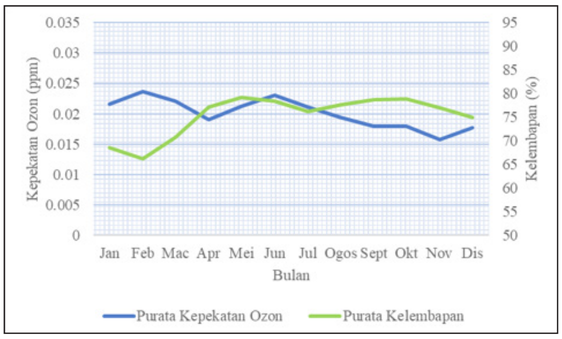
iii. East

FIGURE 5. Relationship between surface ozone concentration and temperature for southwest monsoon and northeast monsoon

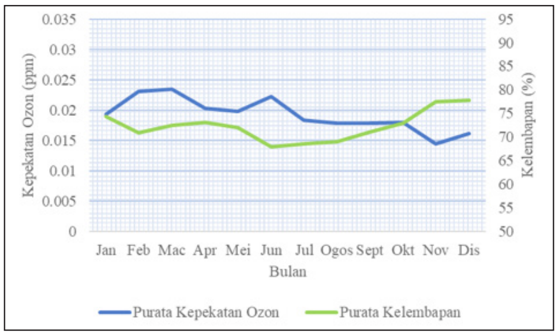
Figure 5 shows the plot line graph for surface ozone concentration for 9 years (2010-2018) for each monitoring station in peninsular Malaysia. The monthly average of surface ozone concentration and temperature of all the stations selected to conduct this study according to the area and monsoon season in 2010 to 2018 was recorded in Figure 5, while the monthly average of surface ozone concentration and air humidity for each station carried out in this study is based on Figure 6. Although the average temperatures for the southwestern monsoon areas are within the range of 26°C to 30°C but based on Table 4.2, the maximum temperature values for the northern and western zones are 40.7°C and 37.6°C respectively. When the southwestern monsoon winds hit peninsular Malaysia especially in the northern and western zones, the concentration of surface ozone increases in the summer (Saini, Taneja & Singh 2017) with temperature values above 30°C. The humidity value of the southwest monsoon season area within the range of 65% to 85% recorded the concentration of surface ozone from 0.014 ppm to 0.025 ppm. The low humidity of the surrounding air indicates that the northern and western regions experience dry and hot weather, hence the production of surface ozone is high which reduces the air quality.

Figure 5 shows that the average surface ozone concentration for the northeast monsoon season is lower than the surface ozone concentration during the southwest monsoon season. The monthly average temperature in the northeast monsoon season is within the range of 26°C to 30°C. The maximum temperature value for the eastern zone is 38.1°C. The average humidity value for the northeast monsoon is higher than the humidity in the north and west zones with a range of 70% to 93% (Figure 6) with a range reading of surface ozone concentrations of 0.01 ppm to 0.023 ppm. When the humidity percentage of air is high, low temperatures will reduce surface ozone production when the northeast monsoon season hit peninsular Malaysia between November and March, east is among the area that is experiencing monsoon season and a higher rainfall distribution than the southwestern monsoon season (Ying, Fook & Glasow 2013).

(a) Southwest Monsoon Season

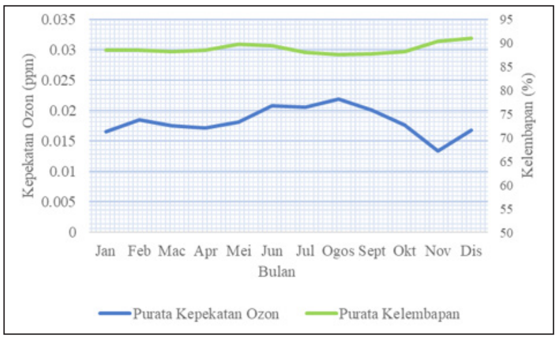


i. North



ii. West

(b) Northeast Monsoon Season



iii. East

FIGURE 6. Relationship between surface ozone concentration and humidity for southwest monsoon and northeast monsoon

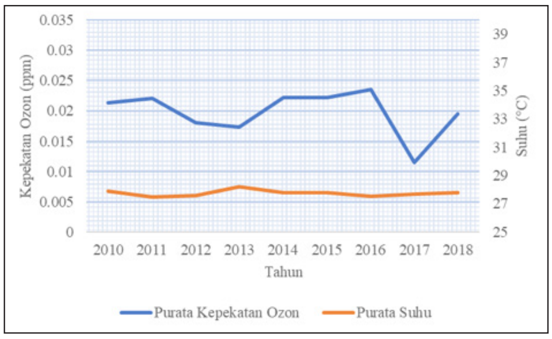
SURFACE OZONE CONCENTRATION ANNUALLY

Figure 7 below shows a line graph of the surface ozone concentration (O_3) and temperature by monsoon season which hit the three selected zones in this study: north, west, and east of Peninsular Malaysia for 9 years starting from 2010 to 2018. Meanwhile, Figure 8 below shows the surface ozone concentration (O_3) and humidity by monsoon season that hit Peninsular Malaysia for 9 years from 2010 to 2018.

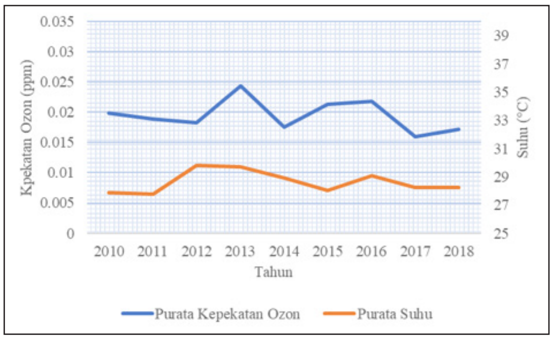
For the southwest monsoon season area in the northern zone, the average temperature of surface ozone and the highest temperature in 2016 was 0.024 ppm and the average temperature for the year was 27°C to 29°C. When the northeast monsoon season hit in the eastern, the average concentration of surface ozone was lower than the surface ozone concentration in the southwest monsoon area. Therefore, the highest average surface ozone concentration for the eastern zone was in 2015 at 0.02 ppm, and at this time, the average temperature was 27°C.

Figure 8 shows the average concentration of surface ozone and humidity by region and monsoon season. The average humidity in areas experiencing northeast monsoon season is higher than the average humidity in areas experiencing southwestern monsoons, indicating that the east coast areas are frequently experiencing rainfall distribution and sunlight intensity that is less than the north and west zones. High humidity will cause the lower production of surface ozone concentrations. Although humidity for an area is high, the production of surface ozone concentration can also be influenced by various human activities such as vehicles and industrial factories.

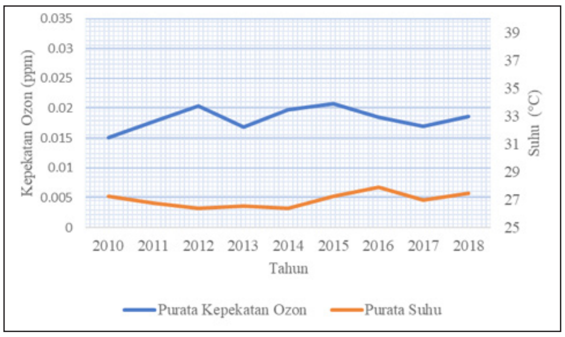
When the southwest monsoon hit Malaysia, the highest humidity recorded in the northern zone was in 2018 at around 80% and the average surface ozone concentration was 0.019 ppm, while in 2013 in the western zone recorded the highest humidity of 86% and the highest average of surface ozone concentration of 0.024 ppm. For zones hit by the east monsoon season such as the eastern zone, the highest average humidity was in 2014 at 98% and the average concentration of surface ozone this year was 0.019 ppm.



i. North

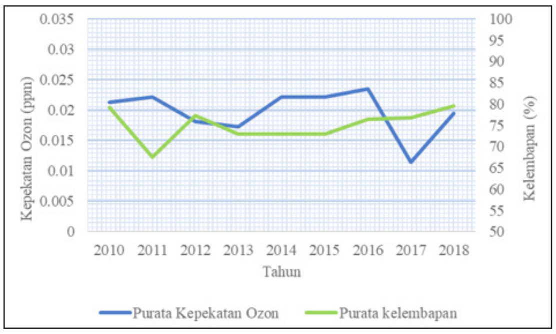


ii. West

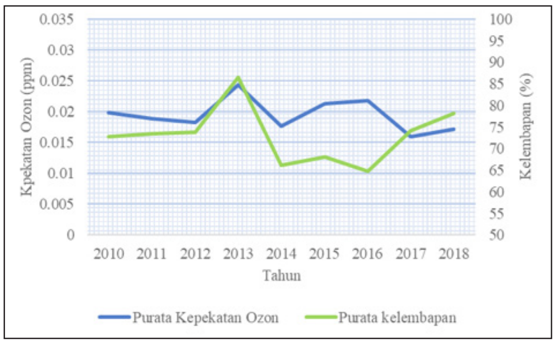


iii. East

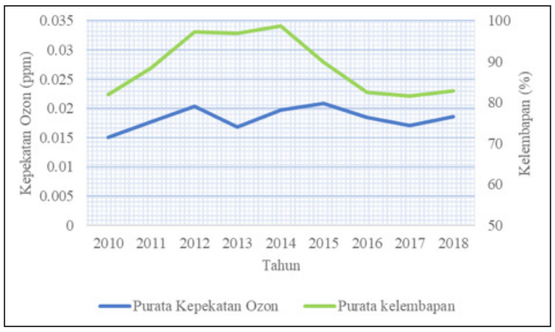
FIGURE 7. Surface ozone concentration and temperature by region annually (2010 - 2018)



i. North



ii. West



iii. East

FIGURE 8. Concentration of surface ozone and humidity by region annually (2010 - 2018)

CONCLUSION

This study requires a high understanding to identify the highest ozone concentration in peninsular Malaysia. This study provides an insight into the concentration of surface ozone and factors that can influence the increase of surface ozone in the study areas: north, west, and east zones. According to the descriptive analysis obtained from 2010 to 2018, the highest monthly average concentration of surface ozone in the north zone is higher than in the western and eastern zone. The hourly average concentration of surface ozone was recorded at the western zone is the highest reading between the three zones in the afternoon. At noon is the most intensity of sunlight and when responding with other pollutants will result in an increase of surface ozone concentration (O_3). Meanwhile, the average of surface ozone concentration at night decreases due to the absence of sunlight, thus photochemical reactions are not possible at this moment.

The average temperature in the summer is higher than the temperature when northeast monsoon season hits peninsular Malaysia. The temperature had caused the increase of the surface ozone concentration. The relationship between the surrounding temperature is directly proportional to the formation of ozone. The higher the temperature, the higher the concentration of surface ozone. However, humidity is less affected by the level of surface ozone concentration, this is because Malaysia is a country that experiences summer and humidity throughout the year. At high temperatures, low humidity can cause an increase in the concentration of surface ozone. Increased of surface ozone concentration that respond to contaminated air composition are a source of air pollution (Sharma et al. 2016).

In conclusion, in this study, the objectives were achieved. The daily, monthly, and annual concentrations of surface ozone for the southwestern monsoon season areas: Kedah and Selangor are higher than the northeast monsoon season area: Pahang. Analysis of surface ozone by area and season variations increased during summer are associated with meteorological parameters such as atmospheric temperature (Molina et al. 2017) and humidity, while the concentration of surface ozone is low during the northeast monsoon season. In addition, the concentration of surface ozone can also increase when there are other environmental influences such as the release of pollutants from anthropogenic activity.

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