World Academy of Science, Engineering and Technology
International Journal of Environmental and Ecological Engineering
Vol:7, No:2, 2013

An Assessment of Ozone Levels in Typical Urban Areas in the Malaysian Peninsular

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Open Science Index, Environmental and Ecological Engineering Vol:7, No:2, 2013 publications.waset.org/855/pdf

***Abstract*—**Air quality studies were carried out in the towns of Putrajaya, Petaling Jaya and Nilai in the Malaysian Peninsular. In this study, the variations of Ozone (O_3) concentrations over a four year period (2008-2011) were investigated using data obtained from the Malaysian Department of the Environment (DOE). This study aims to identify and describe the daily and monthly variations of O_3 concentrations at the monitoring sites mentioned. The SPPS program (Statistical Package for the Social Science) was used to analyze this data in order to obtain the variations of O_3 and also to clarify the relationship between the stations. The findings of the study revealed that the highest concentration of O_3 occurred during the midday and afternoon (between 13:00-15:00 hrs). The comparison between stations also showed that highest O_3 concentrations were recorded in Putrajaya. The comparisons of average and maximum concentrations of O_3 for the three stations showed that the strongest significant correlation was recorded in the Petaling Jaya station with the value R^2= 0.667. Results from this study indicate that in the urban areas of Peninsular Malaysia, the concentration of O_3 depends on the concentration of NOx. Furthermore, HYSPLIT back trajectories (-72h) indicated that air-mass transport patterns can also influence the O_3 concentration in the areas studied.

***Keywords*—**Ozone, Precursors, Urban, HYSPLIT trajectory analysis.

I. Introduction

AIR pollution in urban areas is often the cause of exhaust gases from vehicles, combustion in industries and from domestic purposes. The common pollutants are carbon monoxide, nitrogen oxides, sulphur dioxide and ozone. With an increase in industrialisation, many developing and develop countries, especially the large cities, are experiencing excessive levels of these pollutants. Consequently, controlling air pollution has become a global challenge, to comply with the environmental standards as well as to assess the effectiveness of control policies. These steps are expected to provide more insight to the role of the different physiochemical processes in the troposphere.

Surface O_3 is a very strong oxidising agent. It is by-product of the photochemical reaction between carbon compounds such as VOCs, CO and CH_4 with NO_x. The reactions are initiated in the presence of sunlight [8], [21]. The chemical reactions involve the production and the destruction of O_3 simultaneously. Photochemical smog is another by-product of the same reactions, irrespective of the degree of pollution in the atmosphere [22], [23]. Collectively, NO_x and VOCs are referred to as O_3 precursors [1].

The reaction is heavily dependent on the concentration of NO present in the atmosphere [10]. Other factors also have a significant impact on the process of photochemical O_3 production [9]. These are mostly climate-related factors, such as temperature, cloudiness, sunlight, wind speeds and directions, humidity and solar radiation. Consequently, alterations in the climatic condition affect the surface O_3 concentrations. Change rapidly accompanying the change in wind speed and direction, temperature, humidity, and solar radiation.

Previous investigators reported that local variations of O_3 can be influenced by the number of motor vehicles which act as the major sources of oxides of nitrogen (NO_x), voltaic organic carbons (VOCs) and carbon monoxide (CO) [5], [14], [18], [19], [20]. According to [2], [4], [5], [7], [12] due to higher titration processes between nitrogen oxide and ozone, in city centres the concentration of O_3 is lower compared to that observed in the suburban regions.

This study based on the data recorded at the monitoring stations, namely Putrajaya, Petaling Jaya and Nilai over a period of almost four consecutive years, 2008-2011 which are located at urban areas. The aims of this study is to determine the variations of surface O_3 in monthly, daily mean as well as daily maximum recorded at selected monitoring stations. In addition, comparisons of average and maximum O_3 levels based on the backward trajectories calculated using the HYSPLIT Model investigated and discussed.

II. Methodology

A. Background of the Study Area

This study has emphasized on the three locations in Malaysian Peninsular namely Putrajaya (S1), Petaling Jaya (S2) and Nilai (S3). Putrajaya is the centre for administration

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in Malaysia where all the federal government is situated. It is 24 km south of Kuala Lumpur and 20 km from the Kuala Lumpur International Airport and covers an overall area of 49.30 kilometers square. The population is approximately 320,000, which are provided accommodation in the form of 64000 housing units. This station located on a cleared land and close to residential areas.

Petaling Jaya is located in the Selangor state of Malaysian Peninsular. This station is the nearest station to Kuala Lumpur's city centre. As expected with any developed city, Petaling Jaya experiences heavy pollution. Moreover, the topography of the Klang Valley enables the pollutants in the atmosphere to settle down the valley area, thus forming a stagnant condition. Petaling Jaya is surrounded by industries, residential and commercial areas and the area is very compacted.

Nilai is located in Negeri Sembilan and has undergone a state of socioeconomic development. Recently houses and shop lots are being developed around Bandar Baru Nilai. In 1990s, the population of this area was 1719 people. However due to the increase in the development of commercialised areas including Nilai Industrial Park, Nilai Industrial Estate, Nilai Square and etc, these development has created new economic look to Nilai that attract migration to these areas. In fact, these factors had created job opportunities which lead to the intense increased in population.

B. Data Collection

The air quality data collected over a four year period (2008-2011) from January to December which although owned by the Department of the Environment (DOE) in Malaysia are managed by a private company Alam Sekitar Sdn. Bhd. (ASMA).

C. Trajectory Analysis

Backward trajectories analysis demonstrates the main sources contributing to O_3 during peak O_3 days. The chosen height level of the particles release ensured that the trajectories started in the atmospheric boundary layer [15], [16]. The backward trajectories were observed at 1500 UTC and 1700 UTC for 1000, 500, 10 m centroid locations. The backward trajectories atmospheric pollutants were using the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) Model developed by the National Oceanographic and Atmospheric Administration (NOAA) Air Resource Laboratory (ARL). Backward trajectories have been developed for 72 hour for each of the high O_3 days on the 9th of January 2011 (North East Monsoon), the 10th of February 2011 (North East monsoon) and the 9th of December 2011 (North East Monsoon).

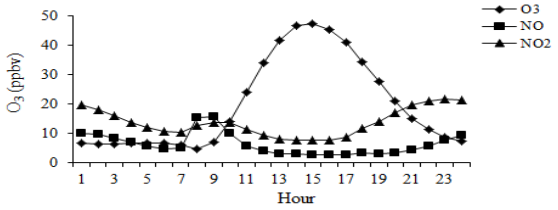
III. Results

A. Diurnal Variations of O_3 Concentration

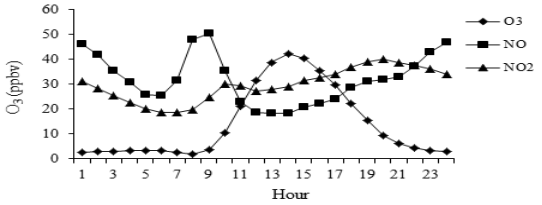
Fig. 1 demonstrated that the hourly averaged diurnal variation of O_3, NO and NO_2 are based on data obtained from a series of hours for each station location study and the distinct diurnal cycle of the measured pollutant concentration was observed. The highest concentration of O_3 was recorded in the afternoon between 13.00 and 15.00 hour. This showed that Putrajaya station (S1) had the highest concentrations of O_3 daily and the second highest concentration was found in Petaling jaya (S2) station. Conversely, Nilai (3) station had the lowest level O_3 concentrations among the selected study sites. Among three study areas shows Nilai in which industrial and commercial trading activities are most prominent. Moreover, the maximum values range of O_3 concentration was close to 47 ppbv in Putrajaya, 42 ppbv in Petaling Jaya and 37 ppbv recorded in Nilai. In the urban areas, high concentrations of O_3 are caused by a reduction factor of NO; the large quantity of vehicles resulted in a lot of release of NO_X followed by UV irradiation of the strains which is high in the meanwhile.

Based on the results, the concentration of NO_2 was found to be stable from midday towards the late afternoon and is usually produced by motor vehicles; this tendency is occurred in Putrajaya (S1) but at lower values of NO_2 concentration. In Petaling Jaya (S2), the tendency of NO_2 indicates a significant peak of NO_2 concentration at around 09:00 am before it decreases towards midday it is increased again in the early evening. Hence, around Petaling Jaya's residential areas where the majority of the residents travel by motor vehicles on the outskirts of Petaling Jaya these fluctuations give an indication of the movement of motor vehicles especially during that hour. It is manifested from the results that the level of traffic lowers the concentration of NO_2 and was expected to be low in the atmosphere during working hours. The results showed that the highest concentration of ozone was recorded in Putrajaya (S1), Petaling Jaya (S2) and Nilai (S3) at around 2:00 pm in the afternoon.

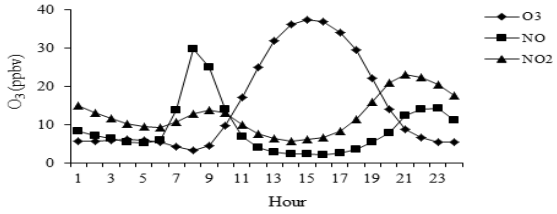
Studies conducted by [6] reveal that ozone variation tended to comply with the general behavior which usually reported an increase in ozone levels during the day. This increase was related to photochemical processes of ozone production in the mixing layer and transport from the upper layer. Both processes were facilitated by solar radiation, and lower values at night because of in situ destruction of ozone by deposition and the reaction between O_3 and NO.



S1



S2



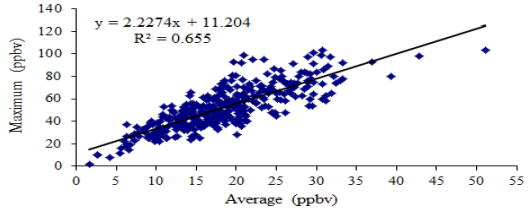
S3

Fig. 1 Diurnal variation of O_3, NO and NO_2 recorded at Putrajaya (S1), Petaling Jaya (S2) and Nilai (S3) stations

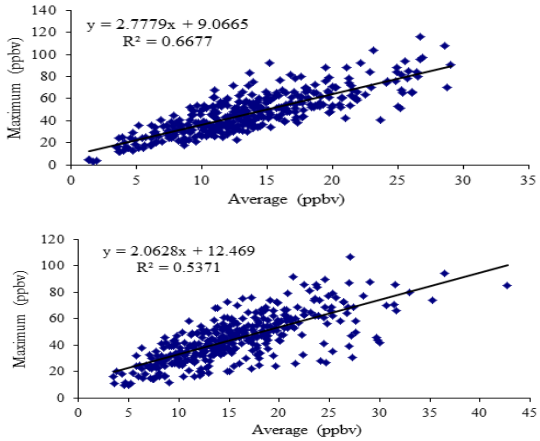
B. Comparisons between Average and Daily Maximum

The statistical computational analysis of the correlation matrix between maximum value daily and average value daily in the three stations indicated that the maximum daily value has a significant positive correlation over the average daily value. As indicated from the scree plot, there is a direct relationship between the plotted points of the maximum daily and the average daily as a result of the positive slope. Hence, the correlation coefficients and slops are positive. Correlation value showed that the positive independent X and dependent Y equation of the line. From Fig. 2 below, the correlation value for Putrajaya (S1) was at (R^2= 0.665, Petaling Jaya (S2) was at R^2= 0.667 and Nilai (S3) was at R^2= 0.537). In effect, the concentration of air pollutants with reference to O_3 level in the three stations tends to be on the increase. A similar trend was also observed in the atmospheric data collected from the three stations from 2008 to 2011. The urban areas showed an upward trend their O_3 concentrations.

On comparing the average and maximum concentrations of O_3 for the three stations, it can be deducted that the strongest significant correlation was recorded in Petaling Jaya (S2) station with the value R^2= 0.667. Thus it can be inferred from the correlation pattern that there were similarities in the source of atmospheric pollutants recorded in Nilai (S3). Meanwhile, the second most significant correlation was recorded in Putrjaya (S1) with (R^2= 0.665). Petaling Jaya (S2) is suited in the urban and industrial hub of Malaysia and as expectedly, the movement of motor vehicles, pollutants from various sources and as well as fumes from the industry will play a dominant role in the atmospheric pollution of the city.



S1



S3

Fig. 2 Average and daily maximum variations of ozone concentration at Putrajaya (S1), Petaling Jaya (S2) and Nilai (S3) stations

C. Comparisons of the Yearly Average Concentrations of O_3 for the Three Study Areas

Fig. 3 showed the annual average from 2008 to 2011 for the three study areas. The overall results of the graphics 'box plot' showed the highest average concentrations of O_3 over the years. It was apparent Putrajaya station (S1) recorded the highest average concentration in 2008. The value of the second highest reading was recorded in Petaling Jaya (2) station in 2008. Nilai station (S3) recorded the lowest average yearly concentration among the three stations in 2011. As can be seen from the results Putrajaya (S1) station was recorded the highest among the three stations in the study area in 2008 of a maximum average of O_3 concentrations.

However, the lowest average yearly reading was at Putrajaya in 2009. The value of the second lowest was also recorded at Petaling Jaya (S2) in 2011. The comparison of the yearly concentration of ozone between three stations shows that Putrajaya (S1) in 2008 had the highest average in relation to other study regions.

The ozone concentration increased in 2008 at Putrajaya (S1) in spite of the fact that in 2009 due to haze episodes it decreased. The concentrations started to increase from the year of 2008. The increase in concentrations is probably because of industrial activities that were being conducted in Putrajaya districts. The haze conditions may also affect the high concentrations of ozone in Putrajaya. Regarding the O_3 concentration in Petaling Jaya (S2), the concentration recorded during 2008 and 2010 due to motor vehicles activities. Nilai (S3) station on the other hand revealed a decreasing pattern. Due to differences in economic activities, by which no industrial areas existed in Nilai (S3), the concentrations of ozone may be as a result of the motor vehicles activities and construction activities outside city center which might include land clearing.

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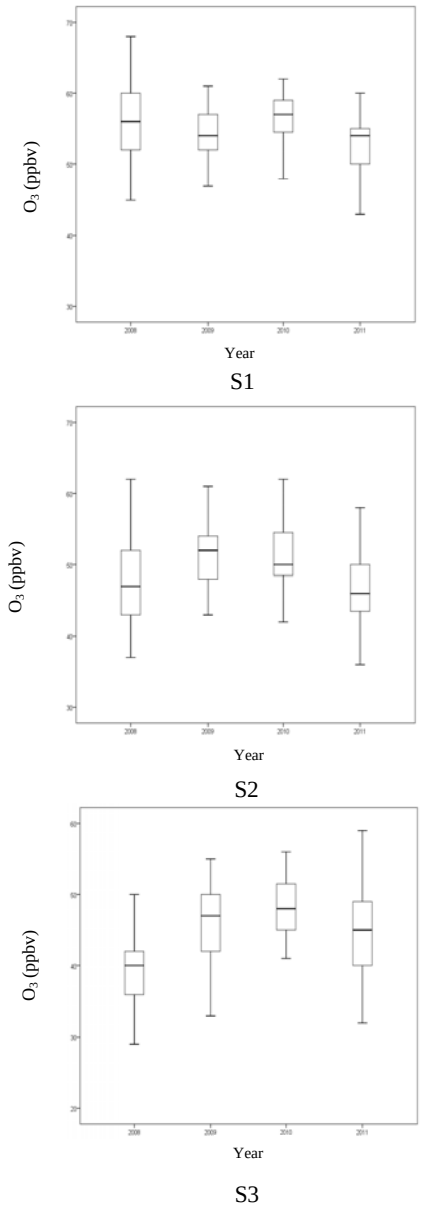


Fig. 3Annual O_3 concentration recorded at Putrajaya (S1), Petaling Jaya (S2) and Nilai (S3) stations

D.Comparisons of the Trajectory Concentrations of O_3 for the Three Study Areas

To examine the concentration of O_3 in our study area which are Putrajaya (S1), Petaling Jaya (S2) and Nilai (S3), a back trajectory analysis was adopted using Hybrid Single-Particle Langrangian Integrated Trajectory (HYSPLIT) model to track the transportation routes of O_3 before at the monitoring locations. From the Fig.4 in the text, the wind movement originated from 10 meters above the sea level at all the three monitoring stations within 72 hour. During the inter-monsoon season, the wind system is more veracious. On the other hand, the north-east monsoon is usually connected to the wet season in West Peninsular which occurs annually between November and March. The amounts of anthropogenic sources are not affected as a result of the biomass burning especially coming from east Malaysia peninsular. Literatures have shown that O_3 concentration increases in the dry season and is caused by factors such as: high temperatures and UV radiation, which is at the maximum strain and pressure [3], [7], [11], [13], [17], [24].

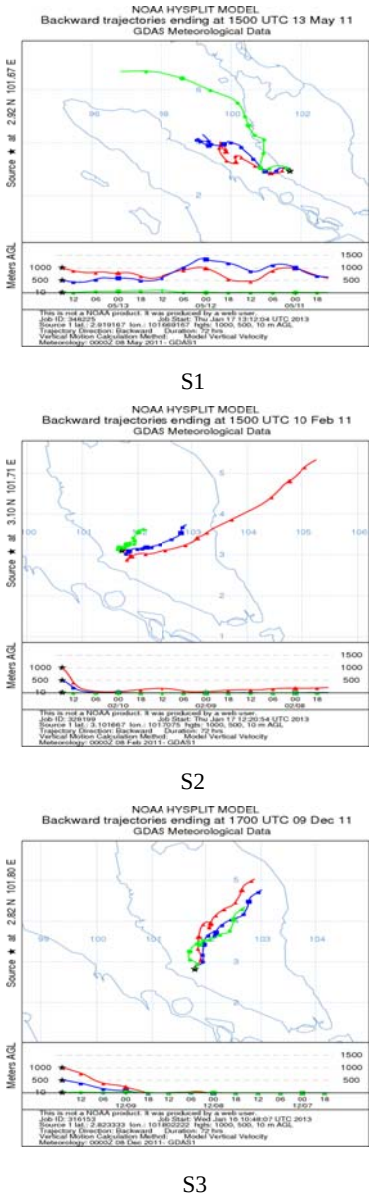


Fig. 4 Backward trajectory of wind direction for the Putrajaya (S1), Petaling Jaya (S2) and Nilai (S3) monitoring stations for the highest O_3 episode in 2011

IV. Conclusion

In this study, the O_3 levels in three Malaysian cities were observed from 2008-2011 and analyzed using HYSPLIT Model. This study shows that the intensity of the solar radiation and as well as its titration processes contribute immensely to the diurnal concentration of O_3. Amongst the sampled cities which are; Putrajaya (S1), Petaling Jaya (S2) and Nilai (S3), Putrajaya (S1) has the highest level of O_3

level concentration caused by motor vehicle whereas in Nilai (S3), major causal of the high concentration of O_3 is industrial and commercial trading activities.

However, It is observed from the studies that there are daily fluctuations in the level of O_3 with the maximum emission of O_3 occurring during noontime from (13:00 -15:00) as a result of photo oxidation of the precursor gases and lower concentrations were observed during night and morning. Meanwhile, in the lifetime of the study period, 2008 and 2011 recorded the highest level of the O_3 level concentration. Inference from backward trajectories shows that there are high possibilities of pollutants being transported from the highly polluted areas could significantly influence the air quality in the less polluted areas. As illustrated by the HYSPLIT Model, temperature and wind direction can also influence the concentration of O_3 in the atmosphere of the area being studied.

ACKNOWLEDGMENT

The authors would like to thank Universiti Kebangsaan Malaysia and the Malaysian Department of the Environment (DOE) for being provided with all the necessary investigation information and air quality data in the process of conducting research. Thanks are due to the NOAA Air Resources Laboratory (ARL) for the provision of the HYSPLIT transport and dispersion model and/or READY website (http://www.arl.noaa.gov/ready.html) used in this investigation.

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