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# Time Series Evaluation of Ozone Concentrations in Malaysia Based on Location of Monitoring Stations

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## ABSTRACT

Over the last decade, ozone emerges as one of the main air pollutant of concern in Malaysia. Increasing in ozone precursor sources has been promoting the ozone production. The aim of this paper was to evaluate the trend and status of ozone concentration in Malaysia for 2009. Four different type of monitoring stations were selected to be evaluated in the study. Kajang was chosen to represent urban, Bakar Arang for sub urban, Seberang Perai for industrial, and Jerantut for background station. The result showed that, urban station demonstrated the highest ozone concentrations that up to 143 ppb, while Jerantut produced the lowest ozone concentration with average concentration around 28.44 ppb. Kajang also recorded the highest number MAAQG limit exceedences followed by Seberang Perai. Bakar Arang and Jerantut did not experience any exceedences during 2009.

**Keywords:** *background station, exceedences, ozone, sub-urban, time series plot, urban*

## 1. INTRODUCTION

Growth in population and rapid development were proved to negatively impact the air quality status around the world. In Malaysia, ground level ozone becomes one of the most significant air pollutants due to the increasing sources of ozone precursors. There are no significant primary emissions of ozone in the atmosphere, because ozone is secondary pollutant that created by chemical reaction that occurs in air (Abdul-Wahab et al., 2005). In ambient air, ozone was generated when its precursors such as nitrogen oxides ($NO_x$) or volatile organic compounds (VOCs) chemically reacted in the presence of UV radiation (hv<430nm) from sunlight. According to Mohammed et al. (2012), ozone precursors can arises from natural, mobile, and stationary sources such as vegetation, vehicular, and power plant emissions.

Numerous studies have reported ozone trend and status in Malaysia environment. Azmi et al. (2010) reported that ozone concentrations are predominantly related to regional tropical factors (biomass burning) and intensity of UV radiation. Meanwhile, Ghazali et al. (2010) proposed possibility to predict the ozone concentration using Multiple Linear Regression (MLR). In addition, Mohammed et al. (2012) reported different climate between Malaysia and European countries affected the percentage of crop reduction due to effect of ozone pollution.

This study was conducted to evaluate the trend and status of ozone concentration in several monitoring stations across Malaysia. The relationship between stations location, population, and land use towards the variability of ozone concentration were explored. Due to minimal studies focusing on variability ozone concentrations in Malaysia, this study was aimed to provide additional information concerning the trend and status of ozone concentration in Malaysia conditions.

## 2. METHODOLOGY

### 2.1 Monitoring Stations

The stations that have been used in this study located throughout Malaysia. Four stations were chosen in the study to describe the time series of hourly ozone concentration fluctuations. Each station was representing four different type of monitoring stations as categorised by Department of Environmental, Malaysia. Seberang Perai was selected to represent industrial station. Located in heavily industrial areas in Northern Region of Malaysia, Seberang Perai covers an area about 738km$^2$. This area experienced uniformly high temperature in between 22-24$^o$C during nighttime and around 27-30$^o$C during daytime with mean annual rainfall of 267 cm (Md Yusuff et al., 2010).

Monitoring station which is located in Kajang, Selangor was selected to represent the urban station. Strategically located at Country Height, Kajang, this station was surrounded by heavily populated residential areas and consequently congested roads particularly during morning and evening rush hour. In 2010, there are about 506,526 people resided in Kajang areas which made Kajang one of the most heavily populated areas in Selangor.

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The sub urban stations were stations that located at the sub urban areas which are having less population compared to an urban area. Monitoring station located at Sek. Keb. Bakar Arang, Sungai Petani, Kedah was choose to represent the sub urban station.

Jerantut is one and only background stations that have been establish by Department of Environment, Malaysia. Strategically located at Pejabat Kajicuaca Batu Embun, Jerantut, this station was expected to be minimally affected by vehicular and industrial emissions. Detail of the stations used in this study was depicted in Table 1.

**Table 1 Detail of ozone monitoring stations**

| Stations Name | Coordinate | Stations type | Population |
|---|---|---|---|
| Seberang Perai, Pulau Pinang | N05°22.265, E100°23.344 | Industrial | 926,340 |
| Jerantut, Pahang | N03°58.238, E102°20.863 | Background | 33,606 |
| Bakar Arang, Kedah | N01°29.815, E103°43.617 | Sub urban | 421,530 |
| Kajang, Selangor | N03°04.636, E101°30.673 | Urban | 506,526 |

## 2.2 Ozone Monitoring Records

Hourly ground level ozone concentrations were obtained from Air Quality Division of Department of Environment, Malaysia (DoE). Strict regulations and standard quality control procedures were applied by DoE to ensure the quality of the data produced. One year of continuously ozone concentration records (January to December 2009) were analyzed in this study.

Hourly ground level ozone concentrations in ambient atmosphere were obtained using a UV Absorption Ozone Analyzer Model 400A which applied a system based on the Beer-Lambert Law (Mohammed et al., 2012). The missing data or incomplete data matrices are normally result from insufficient sampling, errors in measurements or fault in data acquisition (Junninen et al., 2004) that were encountered in the study are directly omitted and not considered during the analysis.

# 3. RESULT AND DISCUSSIONS

## 3.1 Long Term Ozone Air Quality Record

The descriptive statistics of ozone concentration in Kajang, Seberang Perai, Bakar Arang, and Jerantut were shown using box and whisker plot and descriptive statistics table, as shown in Figure 1 and Table 2 respectively. Figure 1 and Table 2 demonstrated that, the highest ozone concentration was recorded in Kajang with maximum value up to 143 ppb, followed by Seberang Perai with maximum value of 105 ppb, Bakar Arang (90 ppb), and Jerantut (60 ppb). However, based on the mean value, Bakar Arang (44.23 ppb) was recorded a higher concentration compared to Seberang Perai (40.66 ppb), while Kajang (56.64 ppb) still recorded the highest mean of ozone concentration, while Jerantut recorded the lowest concentration (28.44 ppb). Sansuddin et al. (2011), indicated that mean values are very sensitive to large and small monitoring records and at the same time it can represent the skewness of the data distribution. Result from box and whisker plot suggest that, distribution of data at Kajang and Seberang Perai were skewed to the right (median < mean), while uniformly distributed data was illustrated in Bakar Arang and Jerantut (median = mean). Low dispersion of data (small interquartile) was recorded in Jerantut compared to the other three stations.

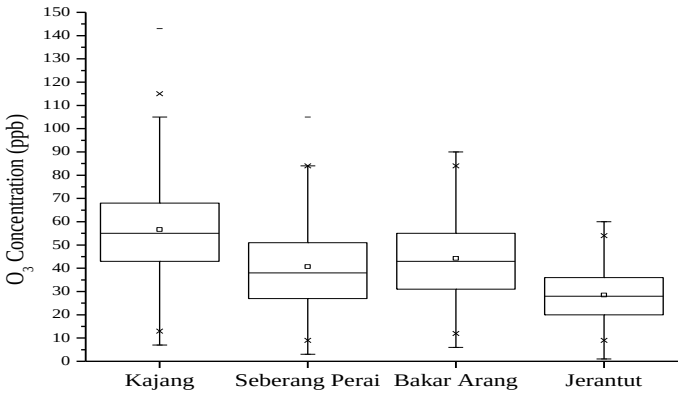


**Figure 2 Box and whisker plot of ozone concentration in 2009**

**Table 2 Descriptive Statistics of Hourly Ozone Concentration at (a) Kajang; (b) Bakar Arang; (c) Seberang Perai; (d) Jerantut**

| Station | N total | Mean | Standard Deviation | Minimum | Median | Maximum |
|---|---|---|---|---|---|---|
| Kajang | 365 | 56.64 | 20.01 | 7 | 55 | 143 |
| Seberang Perai | 365 | 40.66 | 17.14 | 3 | 38 | 105 |
| Bakar Arang | 365 | 44.23 | 16.59 | 6 | 43 | 90 |
| Jerantut | 365 | 28.44 | 10.57 | 1 | 28 | 60 |

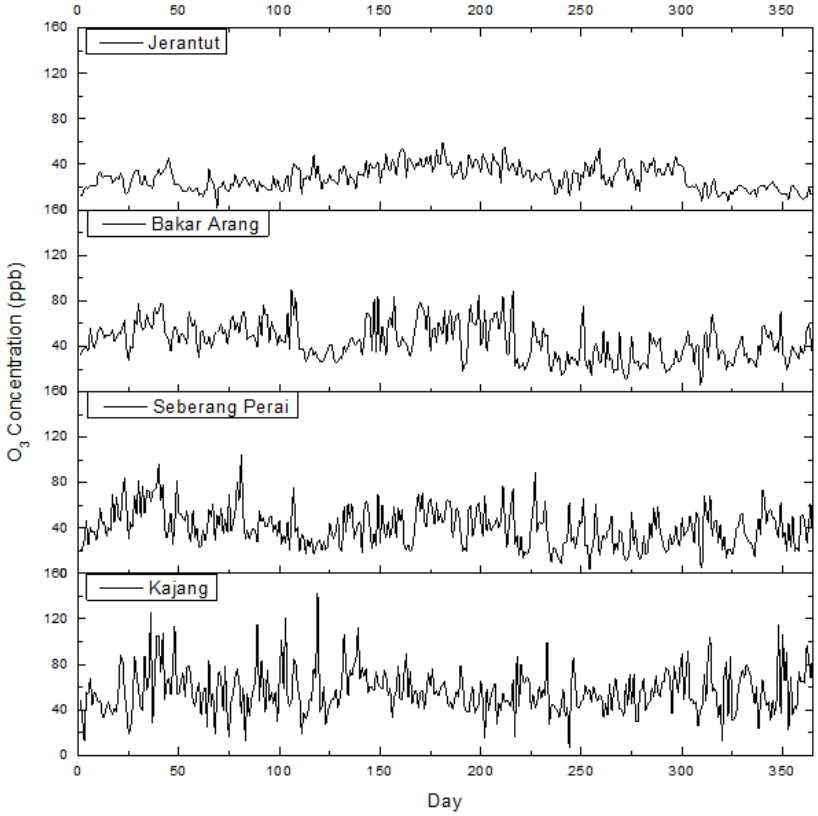


**Figure 2 Time series plot of hourly ground level ozone concentration for (a) Kajang; (b) Bakar Arang; (c) Seberang Perai; (d) Jerantut during 1999 to 2010**

## 3.2 Ozone Concentration Time Series Analysis

Figure 2 showed the time series plots of ozone concentration in the studied stations. Time series plot can be graphically used in describing the fluctuational behavior of the ground level ozone concentration for a certain location and period.

From Figure 2, ground level ozone concentrations are fluctuated throughout the years. Based on Environmental Quality Report (2010) several unhealthy air quality days were reported during 2009 especially in Kajang. Here, several distinct peaks can be observed from the time series plot with the highest peak concentration (143 ppb) recorded in April 2009. In Kajang, high ozone concentration were recorded during February to April with several peaks that surpassing the Malaysia Ambient Air Quality Guidelines (MAAQG) for one hour (100 ppb). Lower concentration recorded on Jun to September. Located in heavily populated urban areas, Kajang were expected to face large number of vehicular emissions especially during morning and evening rush hour. Ghazali et al. (2009) reported that, diurnal profiles of daily $NO_2$ concentration showed two distinctive peaks during morning (9.00 to 10.00 am) and evening (8.00 to 9.00 pm) in the urban areas. As $NO_2$ is the main precursor of ozone, increasing in $NO_2$ would leads to the increasing of $O_3$ as well. A study by Azmi et al. (2010) was also reported the same scenario of ozone concentration in urban areas.

The similar results were also observed in Bakar Arang and Seberang Perai monitoring stations, where no distinctive trends of ozone fluctuations were recorded. In Seberang Perai, the highest values were recorded on

March (105 ppb) while in Bakar Arang the highest concentration was occurred on April (90 ppb). Although these stations are different on the type of classification (sub urban and industrial), the observed ozone concentrations however did not gives large differences. The most prominent sources of ozone for both areas were produced by vehicular emissions and industrial establishments.

Jerantut was expected to produce lowest ozone concentration compared to other stations. In this station, ozone was in the range of 1 to 60 ppb with mean value of 28 ppb. Lowest concentrations were recorded during November and December 2009. Minimal source of ozone precursors such as vehicular and industrial emissions were the main factors why the low level of $O_3$ concentration were recorded in Jerantut. According to Azmi et al. (2010), natural forest, open burning, soil dust and low number of motor vehicle are expected to contribute to the air quality status at this station. However, transported ozone pollution from other places may elevate $O_3$ level in the background station (Ge et al., 2012).

## 3.3 Number of Exceedences

Numbers of exceedences at the studied stations in 2009 were depicted in the Figure 3. One exceedence was counted when hourly ozone concentration surpassed the 1-hour MAAQG limits (100 ppb). From Figure 3, the highest numbers of exceedences of $O_3$ concentration were recorded in Kajang with 25 cases. Even though Seberang Perai is located in industrial zones, there was only one exceedence which was happened in March 2009. Meanwhile, there was no exceedence measured in Bakar Arang and Jerantut in 2009. This finding positively showed that, high vehicular emissions which are associated with urban areas are more profound factors that lead in the increasing of ozone concentration compared to the industrial emissions. According to Afroz et al. (2003), vehicular emissions accounted about 70% of the total emissions of air pollution in urban areas.

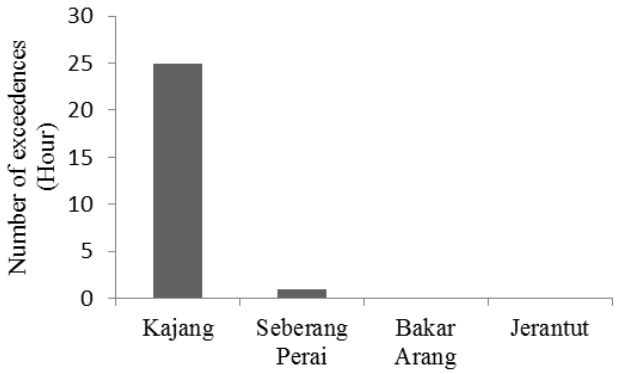


**Figure 3 Numbers of exceedences in the study area**

# 4. CONCLUSION

In accessing the variability of ozone concentration across Malaysia, four stations were selected. Result demonstrated that Kajang stations recorded highest ozone concentration followed by Bakar Arang, Seberang Perai and Jerantut. Kajang also recorded highest number of exceedences with 25 cases on 2009. This scenario suggested that, urban areas faced severest $O_3$ pollution compared to sub urban, industrial and background areas. Urban citizen were exposed to higher concentration of ozone compared to other areas.

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