Diurnal variation of secondary air pollutant concentrations during movement restriction orders in Johor

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Abstract. Secondary air pollutants are those that are formed through chemical reactions between primary pollutants and other substances in the atmosphere. Diurnal variations in secondary air pollutants can occur due to changes in sunlight, temperature, and the presence of other chemicals in the atmosphere. Ground-level ozone is created when sunlight interacts with nitrogen oxides (NOx) and volatile organic compounds (VOCs) in the air. This study focused on secondary air pollution levels during movement restriction orders (MCOs)using hourly average ozone data acquired from the Department of Environment Malaysia in 2020 and 2021 in Batu Pahat station. The data were analyzed using descriptive statistics, time series analysis, and diurnal plot. The diurnal pattern of ozone concentrations showed a consistent trend in the location, with the highest levels observed from noon to evening and the lowest levels at night. Additionally, the study found that ozone levels were highest during the movement control order (MCOs) compared to the conditional movement control order (CMCO) and restricted movement control order (RMCO) with mean values of 18.1 ppb, 14.5 ppb and 17.4 ppb, respectively due to increased sunlight during the summer months. The study findings can be used to identify and study the best conditions to decrease ozone air pollution.

1 Introduction

Ozone is not directly released into the atmosphere by any one source, in contrast to the other air pollutants that meet the criteria. Ozone is a secondary air pollutant at ground level. Nitrogen oxides and volatile organic molecules that are already present in the air mix chemically to produce it. The creation of tropospheric ozone is caused by a reaction between sunlight energy and volatile organic molecules, carbon monoxide, and nitrogen oxides. Emissions from factories, cars, and other forms of pollution all contribute to the formation of tropospheric ozone [1].

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On hot and sunny days, unhealthy ozone concentrations are higher. Both indoors and outdoors, people are exposed.

One of the recent factors of air quality changes is influenced by coronavirus disease. In China, the coronavirus (COVID-19) first appeared in December 2019 as viral pneumonia in China. Coronaviruses are RNA viruses with a positive strand and an envelope from the family Coronaviruses [2]. On March 18, 2020, the Malaysian government issued the Movement Control Order (MCO) in an effort to create more social distance and stop the virus's spread. The MCO order has been extended numerous times. Additionally, the MCO, particularly in the state of Johor, is adhered to quite rigidly.

Due to travel restrictions, only a few essential service sectors, including healthcare, logistics, the food supply system, and finance, are allowed to function. As a result, several flights have been cancelled, and construction and industrial projects have been put on hold. This is because many Malaysian workers who work in Singapore frequently use the Johor crossing board to enter Singapore. As a result, fewer operations have led to lower air pollution levels. Meanwhile, in Malaysia, particulate matter (PM) reductions of 58.4% were first observed over the Peninsular Malaysia region during the MCO period [3]. As been reported by Awang et al. [4] there are a slight decrease in O_3 concentration has been recorded in Shah Alam upon implementation of MCOs. Encouraged by the finding of researchers on air pollutants, this study would like to determine the impact of the MCO on the ground level.

2 Material and Method

2.1 Study Area

Johor was chosen as the study's location specifically at The Batu Pahat monitoring station, which is located southeast of Muar and southwest of Kluang with latitude and longitude of 1.8494°N and 102.9288°E, respectively [5]. Johor was chosen as the study area because residents in Johor prefer to drive their own cars rather than take public transit, and the frequency of driving is much higher than in other parts of Malaysia [6]. The city has an equatorial climate throughout the year with stable temperatures, plenty of rain, and high humidity. The Intertropical Convergence Zone dominates the trade winds in an equatorial setting, and there are no cyclones [6]. Daily average temperatures range from 26.4ºC in January to 27.8ºC [6]. Although the climate is mainly consistent, there is considerable seasonal variation due to the influence of monsoons, with noticeable changes in wind speed and direction, cloud cover, and rainfall volume [6]. Moreover, the area normally experiences traffic congestion during rush hour on weekdays, weekends, and public holidays.

2.2 Data Acquisition and Analysis

The secondary data on ground-level ozone concentrations was obtained from the Department of Environment Malaysia. The data were obtained from the hourly average of the ground-level ozone concentration for 2020 in Johor. The descriptive statistic of data of ground-level ozone concentration was determined to observe the distribution and variation of the data in the study area. The time-series analysis of ground-level ozone was plotted using Origin Pro version 10 to observe the variations of the data against time during the MCOs periods. Meanwhile, diurnal plots were used to display the trends in a given ozone concentration over a period of movement restriction orders at each time throughout the day. Moreover, it also visualizes how secondary pollutant changes in the atmosphere throughout the day. The analysis of this study was carried out during three periods of movement control orders (MCO; 18th March – 1st April 2020); conditional movement control orders (CMCO; 4th -12th May 2020) and recovery movement control orders (RMCO; 1st – 15th September 2020).

3 Result and Discussion

Table 1 shows descriptive statistics of ground-level ozone concentrations in Batu Pahat during 2020 and during the implementation of MCO, CMCO and RMCO. Results showed that the mean concentration of ground-level ozone in 2020 is 16 ppb with the maximum concentration recorded is 84.5 ppb which is significantly lower than the permissible value outlined by Malaysia Ambient Air Quality Standard. Meanwhile, mean ground-level ozone concentrations during periods of MCO, CMCO and RMCO are 18.1 ppb, 14.5 ppb and 17.4 ppb, respectively. Results clearly showed that the maximum concentrations during the enactment of MCO, CMCO and RMCO are significantly lower with a maximum value of only 72 ppb which is believed due to movement restriction orders. Results also indicate that the variation in O_3 concentration during MCO and RMCO is much higher as compared to during CMCO with a standard deviation value is 13.1 for MCO is 15.2 ppb and RMCO is 15.3 ppb. According to Asif [7] the situation is due to residents in the station strictly following rules and regulations during COVID-19 regarding movement control orders. During this period ozone concentration is high due to emissions from a growing number of sources from industrial manufacturing [8].

Moreover, during MCO there are some high peak date ground level ozone such as 18th March, 29th March and 1st April 2020 (Figure 1). It is because, usually the march is a drier period where more sunlight is received hence an increase in ground-level ozone formation [9]. Furthermore, during this time where the government allowed schools to start to operate as usual. When school starts to operate a lot of public transportation, school bus and school van made high traffic density at the station thus contributing to high ozone precursors due to vehicles burning gas for a certain period [10]. During RMCO the ozone concentration is obviously lower than MCO and higher than CMCO in the station. It is because normally during the monsoon season in September month, Malaysia received comparatively monthly lower rainfall thus less ground-level ozone formation occurs during rainy days as the area is shielded by the thick cloud that filters UV radiation. For example, high humidity will cause lower production of surface ozone concentration. 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 [11].

Table 1. Descriptive statistics of ozone concentrations during different MCO in Batu Pahat

Type of MCO	Total (Year)	Mean (ppb)	Standard Deviation (ppb)	Minimum (ppb)	Maximum (ppb)
2020	8784	16.0	12.1	0.0	84.5
MCO	360	18.1	15.2	0.3	61
CMCO	240	14.5	13.1	0.4	61
RMCO	384	17.4	15.3	0.4	72

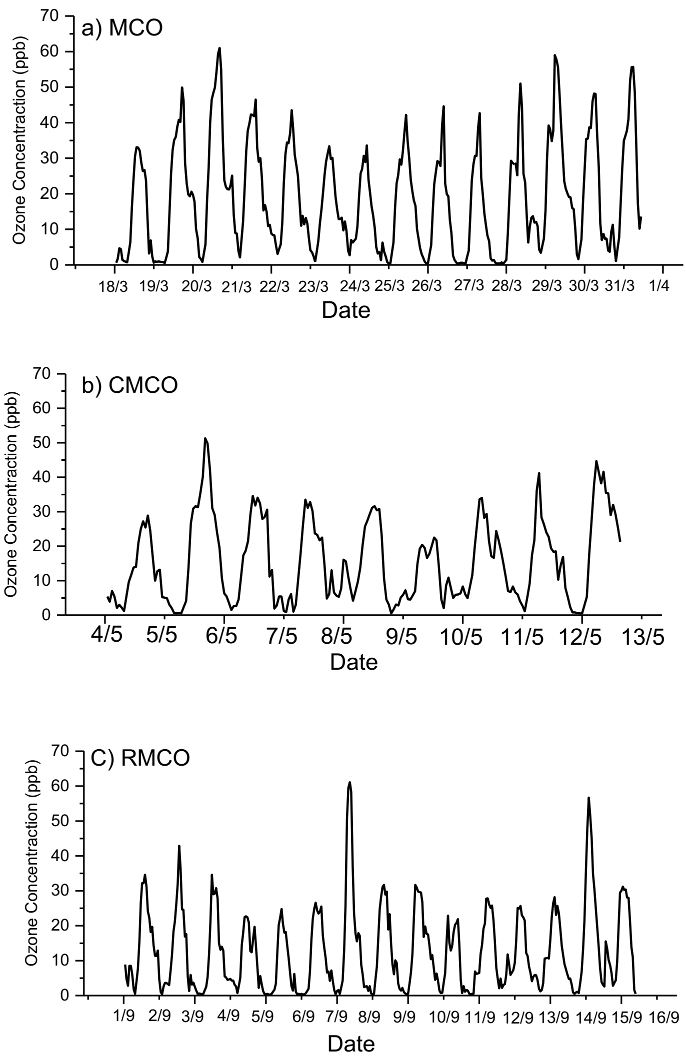

Fig 1. Time series plot of ground level ozone concentration during a) MCO; b) CMCO and c) RMCO

Diurnal variability of ground level ozone during a whole day in station Batu Pahat were analysed using diurnal plot as shown in Figure 2. The diurnal variation of the station during all type of MCOs shows similar pattern but with different magnitude. The diurnal pattern of ground level ozone concentration observed to have maximum concentration during afternoon 1 p.m. to 5 p.m. and minimum concentration during early morning 1 a.m. to 9 a.m. This result is consistent with previous studies [12]. The variation of ground-level ozone concentration RMCO is higher during the afternoon compared to early morning due to the amount of solar radiation during the day, which empowers photochemical reactions and induces ground-level ozone formation.

The highest peak in ground-level ozone concentration was during MCO in Batu Pahat with around 50 ppb recorded during CMCO. However, the lowest peak of ground level ozone concentration at the station occurs at 12 a.m. with 0 ppb during MCO in Batu Pahat. This is because ozone concentrations drop as ozone combines with other chemicals and quickly settles onto various surfaces after sunset, when no more sunlight is available to start ozone synthesis [13]. Ozone concentrations decrease because of their involvement in nitrogen titration reactions [14]. The ground level ozone maximum peak in the station during MCO with the highest 50 ppb in Batu Pahat at 6 p.m. The lowest peak of ground level ozone concentration for Batu Pahat differed by time, at 6 a.m. This phenomenon is due to faster deposition of ground level [15]. This phenomenon might occur due to high concentration of night-time NO that enhances ground level ozone removal which allows the lowest peak during MCO period [16].

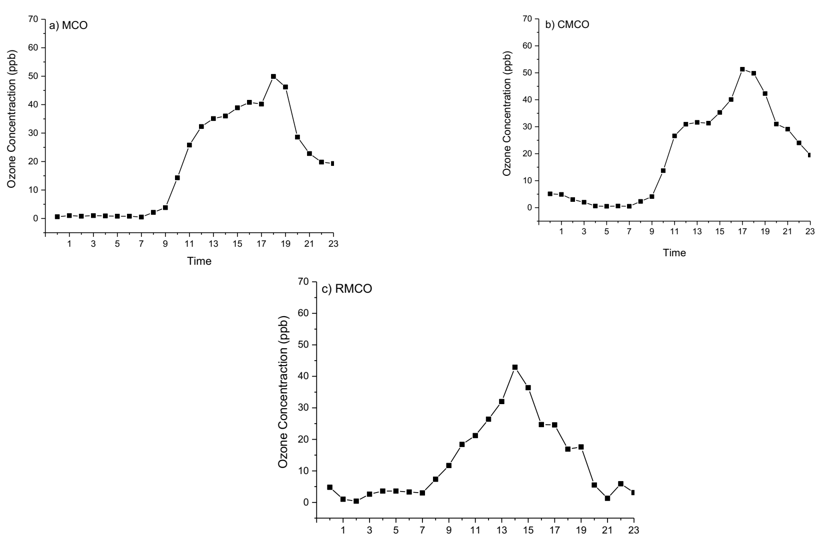

Fig 2. Diurnal plot of hourly average ground level ozone concentration during a) MCO; b) CMCO and c) RMCO

During RMCO, ground-level ozone concentration reached the highest concentration at 2 p.m. with 42 ppb. The result showed that the time for peak concentrations is similar to the normal period as has been mentioned by Awang et al. [12] which peak concentration in Malaysia is normally recorded from around 1 p.m. to 3 p.m. During RMCO, the lowest ground-level ozone concentration is 0 ppb at 12 a.m. This occurs due to nitrogen oxide titration and the reaction with nitrogen dioxide which contributed to nighttime ground-level ozone sinks [17]. Normally morning rush hours are from 1 a.m. to 9 a.m., when automobiles typically emit a high concentration of ozone precursors such as NOx. When the amount of nitrogen dioxide generated by automobiles rises enough, it causes the photolysis reaction of nitrogen dioxide, which produces ground-level ozone. Since ground level ozone concentration progressively increases after the sun is up and reaches its highest concentration during this hour, the largest concentration is observed between 1 p.m. and 6 p.m. [18]. After that, ground-level ozone concentration gradually drops and stays low throughout the night, along with the intensity of solar radiation [12]. Up until the early hours of the following day, there is no solar radiation, nitrogen dioxide deposition, and titration reduce ground level ozone levels [12].

4 Conclusion

This study analysed diurnal variations of secondary air pollutants concentration in Batu Pahat. The result exhibited that ground level ozone maximum diurnal is 50 ppb during MCO. Meanwhile, the time series analysis shows the ground level ozone were fluctuated according to the type of MCO and most of the time depend on its precursor sources. The ground level ozone diurnal pattern peaked in the afternoon to evening (1 p.m. to 6 p.m.) and lower concentration during nighttime. Ground level ozone lowest peak is during the early morning (1 am to 9 am), and the earliest lowest peak is observed in the station at 12 am. The obtained results suggested that the time for peak concentration which normally reached 12 noon to 2 p.m. were shifted to late afternoon due to changes in precursor concentrations as MCOs were implemented in Batu Pahat. The results of the study further highlight how crucial the impact of Movement Control Orders is to air pollution. The conditions in the other MCO phases varied, but thanks to the initial CMCO's tight requirements, there was a significant decrease in ozone concentration. According to the study's findings, Malaysia's government's efforts to stop the spread of the COVID-19 epidemic had a major impact on the concentration of air pollutants there. Additionally, it can be argued that the reduction of outdoor activities, automobile emissions, and emissions from coal-fired power plants all contribute significantly to cleaner air.

6 References

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