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Framework: Local Nighttime Ozone Management and Prevention (LNOMP)

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Abstract: Due to the absence of sunlight and lack ozone production during nighttime, ground-level ozone was labelled as a critical period for ozone depletion. This study proposed a local ozone management and implementation based on the major cause of ozone deflection in chemical reactions during nighttime. Three highlighted locations (Klang, Shah Alam and Petaling Jaya) categorized as the highest NO and NO_2 production was focused on this study (urban and sub-urban area) from 2006 to 2016. The descriptive statistics (O_3 and NO) with population density were analysed as an observation for proposed a new implementation system for reducing O_3 during nighttime and preventing it from contributing the next day concentration. The interaction between O_3 and NO concentration was explained based on diurnal analysis. The crucial time for nighttime O_3 deflection was between 7 PM until 12 AM. Therefore, the local nighttime ozone management was pulled out as the nighttime O_3 reduction was understandable. The framework was consisting a management policy by the federal government, state government and local authority, with a plan for nighttime implementation by local government in Malaysia.

1. Introduction

Ground-level ozone (O_3) has been frequently cited as the most significant air pollutant and has been identified as the major air pollution in the urban areas of Malaysia, such as Klang Valley. In contrast to other primary air pollution, O_3 during daytime was focused compared to nighttime condition [1, 2, 3, 4]. As the major O_3 formation was occur only in daytime. O_3 photochemical reactions are complex chemical reactions that involve nitrogen oxide (NO_x), volatile organic compounds (VOCs) and sunlight as the main reaction catalysts [5, 6]. However, O_3 concentration reduced faster during nighttime [5] which explain the significant different between chemical reaction during nighttime was needed throughout for O_3 reduction study [1, 7]. According to Mohamed–Noor et al. [2], the O_3 concentration at nighttime is maintained at approximately 10 ppb even though O_3 has a relatively short lifetime under atmospheric conditions. In contrast, chemical deposition, transit, and removal activities, particularly NO titration, are principally responsible for the lower O_3 content at night [5].

Variations in O_3 concentration at night have also been extensively studied in the literature [1, 3, 6, 8, 9]. Awang and Ramli [8] reported an interrelation between daytime and nighttime O_3 concentrations in

Malaysia. Specifically, the enhanced nighttime depletion chemical removal in O_3 concentrations influences the O_3 concentrations for the following day. Many studies in Malaysia have examined nighttime ground-level ozone focusing on the reduction agent for O_3 concentration. High nighttime O_3 concentrations in Kemaman were found by Awang et al. [1], which can be attributed to the area's limited nighttime sinking agents, which reduce depletion rates and allow O_3 to remain in the atmosphere. During a haze event, Shith et al. [3] detected a low nighttime NO titration, indicating that O_3 from anthropogenic sources can stay in ambient air. According to Seinfeld and Pandis [5], NO titration was the major contributor to O_3 reduction during nighttime.

As part of New Malaysia Ambient Air Quality Standard (NMAAQS), the Department of Environment Malaysia currently has an ozone standard of 100 ppb and 60 ppb for 1h and 8h ozone, respectively to protect the public. However, O_3 has been challenging to control as the population has increased throughout the years. New air quality management focusing on ozone reduction shall be focusing as the implementation was relevant to all authorities in Malaysia. Ramli et al. [10] develop a local air quality management (LAQM) scheme which is relevant in all major parts in government bodies of Malaysia. Critical Conversion Point (CCP) and Critical Conversion Time (CCT) were focused on the major analysis in understanding O_3 transformations [11]. Therefore, this study aims to propose a local air quality management which focuses on nighttime ozone reduction in Malaysia based on the chemical reaction.

2. Materials and Methods

2.1. Study Areas

Klang and Shah Alam cover areas of approximately 636 km^2 and 290.3 km^2, respectively, and are located in the urban area of Selangor State, which is known for its various industrial activities and congested roads during morning and evening peak hours. Mohamed et al. [12] described Shah Alam as a heavily industrialised area with high pollution, a population of more than half a million and high traffic density. Meanwhile, Petaling Jaya is the nearest station to Kuala Lumpur’s city center. 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 [13]. The coordinates of the study areas were stated in Table 1, while the locations are as shown in Figure 1.

Table 1. Details of the selected study areas

No.	Location	Classes	Coordinate
1	Klang	Urban	3°00'36.0"N 101°24'30.1"E
2	Shah Alam	Urban	3°06'17.1"N 101°33'22.3"E
3	Petaling Jaya	Sub-Urban	3°06'17.1"N 101°33'22.3"E

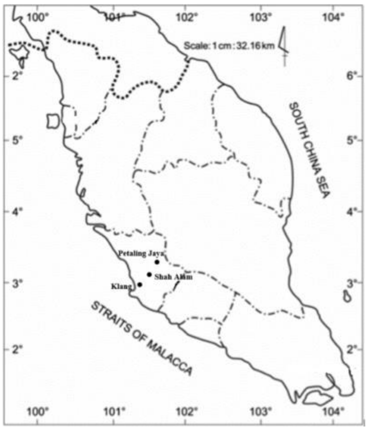

Figure 1. Location of the study areas in Peninsular Malaysia

2.2. Measurement and Instruments

The Air Quality Division of the Department of Environment of Malaysia's Ministry of Natural Resources and Environment provided continuous hourly O_3 and NO data. The data was collected from 2006 to 2016. In the analysis, only data collected between 7 PM and 7 AM, which corresponded to nighttime hours in Malaysia [13], were used. The obtained secondary data were subjected to standard quality control and quality assurance (QA/QC) methods on a regular basis [13]. For continuous monitoring, the QA/QC methodologies employed followed the procedures outlined by internationally recognized environmental authorities such as the US Environmental Protection Agency [9].

Hourly O_3 concentrations were monitored by using the Model 400E UV Absorption Ozone Analyzer [15]. This analyzer follows the Beer-Lambert law and utilizes the internal electronic resonance of O_3 molecules that absorb 254 nm UV light in measuring low ranges of O_3 concentration in ambient air [14, 16]. The ozone analyzer was installed in a weather-proof enclosure fitted with an air conditioner to maintain a stable operating temperature and humidity [9]. Meanwhile, NO concentrations were collected by using the Model 200A NO/NO_2/NOx Analyzer [16, 17], which applies chemiluminescence detection principles to detect NO concentrations in ambient air and has been proven to be sensible, stable and easy to use [15].

2.3. Data Analysis

Continuous data of selected variables are analysed according to spatial location in this study. The average of O_3 concentration and NO concentration visualize the condition of O_3 reading and symbolizes of NO titration occur. No imputation methods were used in this study, and any missing values discovered during data collection were omitted from analysis. Diurnal variation was conducted to identify the variation of ozone during nighttime and daytime of O_3 and NO concentrations. Diurnal analysis shows a slight change of O_3 and NO concentration in one day of 24 hours pattern [18]. However, this study focusing on nighttime duration.

2.4. Local Nighttime Ozone Management

The structure of the basic system of local government system was functional in ensuring further the policies and facilitating the implementation of local nighttime ozone management (LNOM). In the context of ensuring the implementation of a new proposed prevention system to deliver cleaner air in Malaysia, all authorities were important [10]. However, this study only focuses on the local nighttime ozone management (LNOM) policy development and the implementation process in High Nighttime Ozone (HNO) event.

3. Results and Discussion

3.1. Nighttime O_3 and NO Concentration

The average nighttime O_3 and NO concentrations are depicted in Table.2. Nighttime O_3 in Petaling Jaya showed the highest with 16.19 ppb, respectively. Meanwhile, Shah Alam displays the lowest nighttime O_3 concentration with 9.38 ppb. The average nighttime NO concentration of Petaling Jaya displays the highest at 36.09 ppb. In contrast, NO concentration in Klang and Shah Alam was 17.31 ppb and 19.45 ppb. The nighttime elimination chemistry results in a reduced O_3 concentration. At night, the O_3 is stopped at high levels and lost by NOx titration [1, 8]. Furthermore, nightly O_3 removal chemistry is found at night, which can remove O_3 and hence considerably reduce O_3 concentrations in ambient air. As a result, the minimum O_3 concentration at night is zero. Therefore, the existence of NO concentration was increased throughout the nighttime.

Table 2. Nighttime O_3, NO concentration and population density

Location	Average O_3 (ppb)	Average NO (ppb)	Population (census 2010)	Area (km^2)	Population Density
Klang	10.33	17.31	861,189	627.00	1373.51
Shah Alam	9.38	19.45	587,481	191.40	3069.39
Petaling Jaya	16.19	36.09	197,949	97.60	2028.16

The highest population density was stated in Shah Alam as the area was 191.40 km^2 with population 587, 281 (census 2010), while the Klang area has the lowest population density with bigger area of 627.00 km^2. Population growth and increased economic activity in city centres encourage rapid urbanization [19]. The increase of O_3 in Malaysia is largely caused by rapid development due to high usage of motor vehicles which leads to toxic gas releases such as carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and ozone (O_3), as particulate matter (PM_{10} and $PM_{2.5}$) [15]. The population density was used as the symbolic factor for higher development and could lead to highly toxic gases in specific area.

3.2. Diurnal Variation Nighttime of Ozone with Nitric Oxide Concentration

Fig. 2 depicts the average diurnal variation in O_3 and NO concentrations from 2006 to 2016. Between 7 PM and 7 AM, O_3 and NO levels visibly change, indicating that the concentration has clearly fluctuated. The content of O_3 steadily decreases at night due to the termination of O_3 photochemical reactions, as previously stated. Due to the photochemical drive of O_3 production, the diurnal characteristic of overnight O_3 concentrations displays a decreasing tendency after 7 AM across all locations during the study period, as shown in Fig. 2. From 7 PM to 12 AM, a high O_3 depletion is recorded before the O_3 concentration becomes constant. Fig. 2 shows that O_3 concentration in all stations drops drastically when approaching nighttime. This pattern continues until midnight, then it continues to remain steady until 7 AM. Klang stated a decrease from 24.9 ppb (7 PM) to 7.17 ppb (12 AM), Shah Alam displayed 26.56 ppb (7 PM) to 6.00 ppb (12 AM) and Petaling Jaya showed 22.31 ppb (7PM) to 5.75 ppb (12 AM). This is due to NO titration being higher during nighttime as no O_3 production occurs. Meanwhile, NO concentration shows different fluctuation as the concentration steadily increases at night between 7 PM and 12 AM, then continue to deplet until 7 AM. According to Banan et al. [13], the typical patterns of NO diurnal trends are comparable to those of NO_2, with relatively high concentrations found at night and peak concentrations in the morning attributed to vehicle emissions. Furthermore, the nighttime ozone chemistry majorly based on NO_x concentration. Many studies [1, 7, 20] reveal that the chemistry of nighttime ozone differs from that of daytime ozone, with (R1) to (R4) being the most common reactions. However, the major precursor of O_3, NO_x, continues to have the most impact on overnight O_3 changes. According to Awang et al. [1], the reaction of NO and O_3 concentrations, also known as the NO titration process/reaction, controls nighttime O_3 chemistry (R1). The high NO concentrations produced by automotive and industrial emissions stimulate (R1), causing O_3 to be destroyed in the atmosphere. Furthermore, at night (R2), the combination between O_3 and NO_2 can deplete nocturnal O_3 concentrations by converting O_3 to nitrate (NO_3), which then interacts with NO_2 to generate dinitrogen

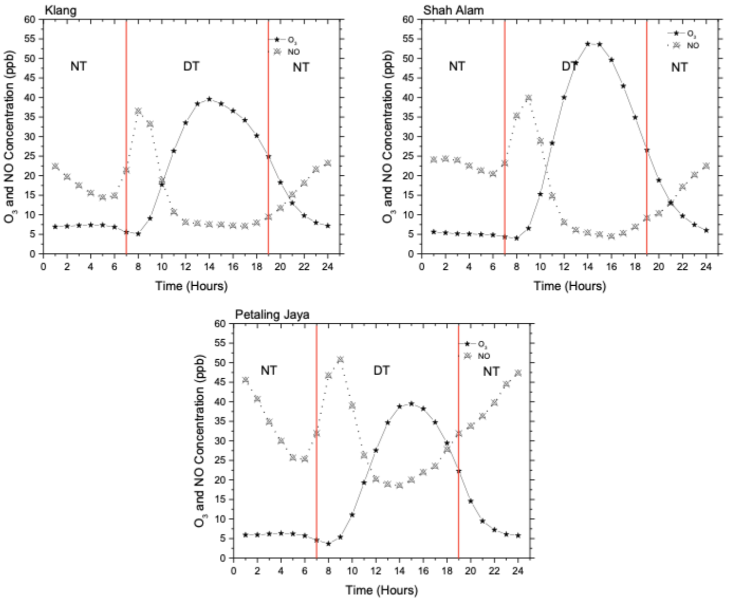

Figure 2. Nighttime and Daytime variation of Klang, Shah Alam and Petaling Jaya

pentoxide (N_2O_5) (R1). The N_2O_5 concentration combines with water in the ambient air to generate nitric acid, which is then eliminated from the atmosphere as acid rain or precipitation.

$$NO + O_3 \rightarrow NO_2 + O_2 \quad \text{(R1)}$$

$$NO_2 + O_3 \rightarrow NO_3 + O_2 \quad \text{(R2)}$$

$$NO_3 + NO_2 + M \leftrightarrow N_2O_5 + M \quad \text{(R3)}$$

$$N_2O_5 + H_2O \rightarrow 2HNO_3 \quad \text{(R4)}$$

4. **Framework of Nighttime Ozone Management**

Local Nighttime Ozone Management (LNOM) in Fig. 3 aims to produce a new implementation on Reducing ozone pollution based on nighttime conditions. The LNOM consist of the policy development and the implementation process for the local authority in Malaysia. LNOM was developed based on the diurnal data in Fig. 2 which explains the major contributor to ozone fluctuations as NOx concentration.

4.1. The Local Nighttime Ozone Management Policy

Fig. 3 shows the Local Nighttime Ozone Management (LNOM) was dependent to the appointment minister from the federal government based on Local Government Act 1976 [21]. In current practices of local management system policy for Ozone prevention as in **1st Phase**. The policy shall consist of collaboration between of federal government council, Department of Environmental, Department of Transportation, Meteorological Department, Department of Health, State Government, City/Municipal/District Government and Local Environment Advisor. The Federal Government have the authority in appointing the Director General in every department in Malaysia which focuses on the environment, transportation, meteorological and health condition in Malaysia. However, the Department of Environment shall be collaborating with the Department of Transportation, Meteorological

Department and Department of Health in analysing nighttime ozone concentration in Malaysia. According to Ramli et al. [10], the Department of Environment is essential in the involvement in the ozone management policy due to their expertise in managing air quality in Malaysia. The cooperation between all departments would enhance the efficiency in preventing high O_3 concentration either in daytime or nighttime. State Governments were acquired in order to manage state activity leading to reducing O_3 production, meanwhile observing District Officer ensure local O_3 management is carried out [10]. In contrast, the local authorities with the city, municipal and district government (administration) shall manage the public space, regulate the preparation of O_3 prevention, control the development and regulate activities that may public nuisances while controlling the pollution levels of a stream [22]. According to Ramli et al. [10], the local authority was important to implement the Local Nighttime Ozone Management (LNOM). The Environmental Quality Act of 1974 (Act 127) [23], as well as other laws, rules, and orders, will be followed by the local authority in carrying out all air quality control procedures.

2^nd^ Phase of Local Nighttime Ozone Management (LNOM) was the implementation shall be done by local authorities which ensured the levelness of O_3 concentration was based on the New Malaysian Ambient Air Quality Standard (NMAAQS). Daily and monthly assessments shall be regularly monitored by local authorities. Nighttime O_3 was evaluated was different compared to NMAAQS as the recommended ozone standard of 100 ppb and 60 ppb for 1h and 8h ozone, respectively to protect the public. It was due to inappropriate 100 ppb shall be achieved during nighttime as no photolysis occurs during nighttime. Therefore, ozone shall be deflecting until zero concentration [8]. In order to attain the targeting concentration during nighttime, a new level of O_3 concentration value shall be propose from the evaluation during nighttime throughout 11 years (2006-2016) condition in Malaysia such in Table 1 and Fig. 2. 12 ppb was proposed as the average of nighttime O_3 concentration as an average of 11 years observation. Meanwhile, the targeting NO concentration during nighttime was expected more than 20 ppb resulting in O_3 reduction shall reach zero concentration. Furthermore, the major contributor to O_3 reduction during nighttime was NO titration [5]. However, there is no NO concentration standard was established. The **2nd Phase** of LNOM was important to be implemented when there was HNO occurs.

5. Conclusion

Nighttime O_3 concentration shall be lookup in managing air quality in Malaysia. Nighttime O_3 was symbolizing the key to deflecting time on O_3 concentration. Therefore, this study aims to create a connection between the major causes of O_3 deflection at nighttime (7 PM to 7 AM) with developing the local nighttime ozone framework in Malaysia. A composite diurnal plot for O_3 and NO concentration was analysed. The O_3 and NO concentrations across all locations followed a similar trend in which O_3 concentration started to deflect at 7 PM until 12 AM. Meanwhile, O_3 after 12 AM until 7 AM was considered constant as there was no ozone production and deflection. In contrast, NO concentration shows different fluctuation as the concentration steadily increases at night between 7 PM and 12 AM, then continue to deplete until 7 AM. The highest NO concentration was located in Petaling Jaya. It explained that the result was eventually significantly influenced by NO titration which become the dominant chemical reaction that controlled nighttime O_3 removal. With the understanding of NO titration as the major chemical contribution to O_3 deflection was NO titration during nighttime, a Local Nighttime Ozone Management (LNOM) was developed based on 2 phases which explain the management policy for the federal government, state government, and local government with selected department and a new implementation procedure with different measurement for nighttime O_3 and NO concentration.

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1st Phase enclosed by (▪ ▪) is for LNOM policy development for HNO preventions.
2nd Phase enclosed by (▬ ▪) is for LNOM implementation process during HNO.

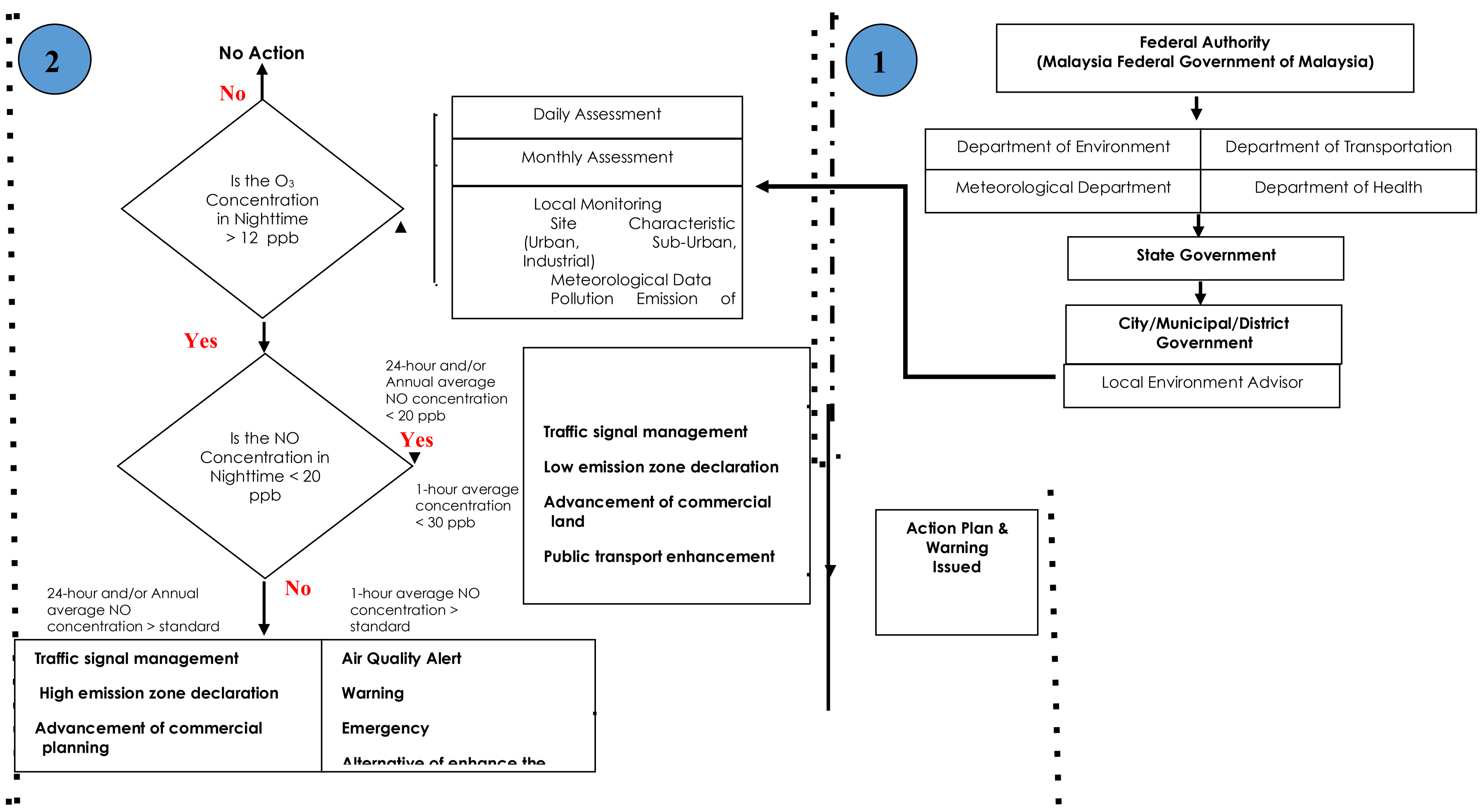

Figure 3. The framework of Local Nighttime Ozone Management (LNOM) during High Nighttime Ozone (HNO)

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