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## Assessment of Ambient Air Pollution in Langkawi Island, Malaysia

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**Abstract.** For many years, Southeast Asia region encountered several ongoing air pollution episodes. These episodes had indirectly significant impact on the air quality of neighboring countries. Hence, this study aims to assess the characteristics and trend of air pollution in Malaysia particularly at Langkawi Island. Air pollution hourly monitoring records from 2003 to 2017 were used in analyzing the statistical data analysis. Eight parameters were selected in this study which known as PM<sub>10</sub>, CO, SO<sub>2</sub>, NO<sub>2</sub>, O<sub>3</sub>, relative humidity (RH), temperature (T) and wind speed (WS). The results showed that the hourly trends of PM<sub>10</sub>, CO, SO<sub>2</sub>, NO<sub>2</sub> and O<sub>3</sub> in Langkawi Island were below the MAAQG standard. The results also indicated that dispersion of PM<sub>10</sub> in Malaysia were significantly affected by temperature, wind speed and relative humidity.

### 1. Introduction

For many years, Southeast Asia region particularly to Malaysia has encountered ongoing air pollution episodes [1]. The worst air pollution episode was reported on 2015 as very unhealthy air pollution levels were detected in Malaysia due to the transboundary haze pollution originated from uncontrolled agriculture burning land and activities in Indonesia [2]. Such episodes posed on high potential of adverse impacts to human health and environment.

Air pollutions can be generated by numerous sources such as power plant, factories, vehicles, windblown dust, haze and open burning of forests or any garbage by human activities as well [3]. In fact, it been reported that the rapid growth of power plant in Malaysia in the past few years [4,5] has contributed to plausible decrease of air quality in Malaysia recently. This is due to the facts that the high amount of waste gas stream emissions from power plants have contributed to continuous release of dust, chemicals, organic and inorganic pollutants into atmosphere during operational hours [6].

The air quality can be represented by the air pollution index (API) as summarized in Table 1. The types of air pollutants being monitored in API are PM<sub>10</sub>, sulphur dioxide (SO<sub>2</sub>), nitrogen dioxide



(NO<sub>2</sub>), carbon monoxide (CO) and ozone (O<sub>3</sub>) which are harmful to human health and environment [7]. When API value is below 50 and 100, it is considered as good and moderate which means that the air surrounding is healthy and safe for the people. If the API exceeds 100, it is considered as unhealthy condition to human and environment. Meanwhile once the API reached to >300 the area is claimed to be hazardous that posed dangerous effects to human health.

Hence, the aims of this work are to assess the characteristics and trend of air pollution in Malaysia particularly at Langkawi Island. The air pollution databases from 2003 to 2017 were used in the statistical analysis and compared with the Malaysian Ambient Air Quality Guidelines (MAAQG) as reference.

**Table 1.** Malaysian Ambient Air Quality Guidelines (MAAQG) [8]

Malaysia's API	
Air Pollution Index (API)	Air Quality Category
0-50	Good
51-100	Moderate
101-200	Unhealthy
201-300	Very unhealthy
301+	Hazardous

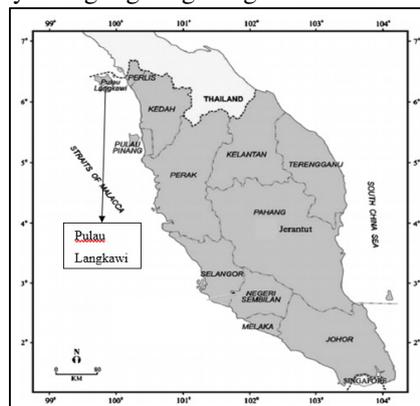
**2. Methodology**

*2.1. Data Acquisition*

Data of air quality monitoring in Langkawi Island was acquired from Department of Environment (DOE), Malaysian. The duration of data collection were from 2003 to 2017. The air pollutant parameters used in this work were PM<sub>10</sub>, CO, SO<sub>2</sub>, NO<sub>2</sub>, O<sub>3</sub> and several of meteorological factors which known as wind speed (WS), relative humidity (RH) and temperature (T).

*2.2. Site location*

Langkawi Island is located on the north of peninsula Malaysia at latitude of 6.3500° N and longitude 99.8000° E with coverage area of 478.5 km<sup>2</sup>. Langkawi Island has been chosen since the island is known as one of the most attractive tourism destination in Malaysia. For instance, it's been reported that the number of tourists in Langkawi kept increasing from 2.4 million in 2010 to 3.63 million in 2016 [9]. In facts, the projection of these numbers is expected to increase until 5 million in 2020 [10]. Figure 1 shows the map of Malaysia highlighting Langkawi Island.



**Figure 1.** Map of Langkawi Island [11].

### 2.3. Statistical Analysis

Several statistical analysis were conducted in order to compare the concentration of the air pollutants and to determine the distribution of air pollutants concentrations. The Pearson correlation analysis was conducted to determine the relationship between air pollutants concentration and the meteorological factors. These data were analyzed using IBM SPSS statistical software and the hourly trends for each air pollutant parameters from June 2003 to 2017 were compared to MAAQG.

## 3. Results and Discussion

### 3.1. Long Term Record of Air Quality Data

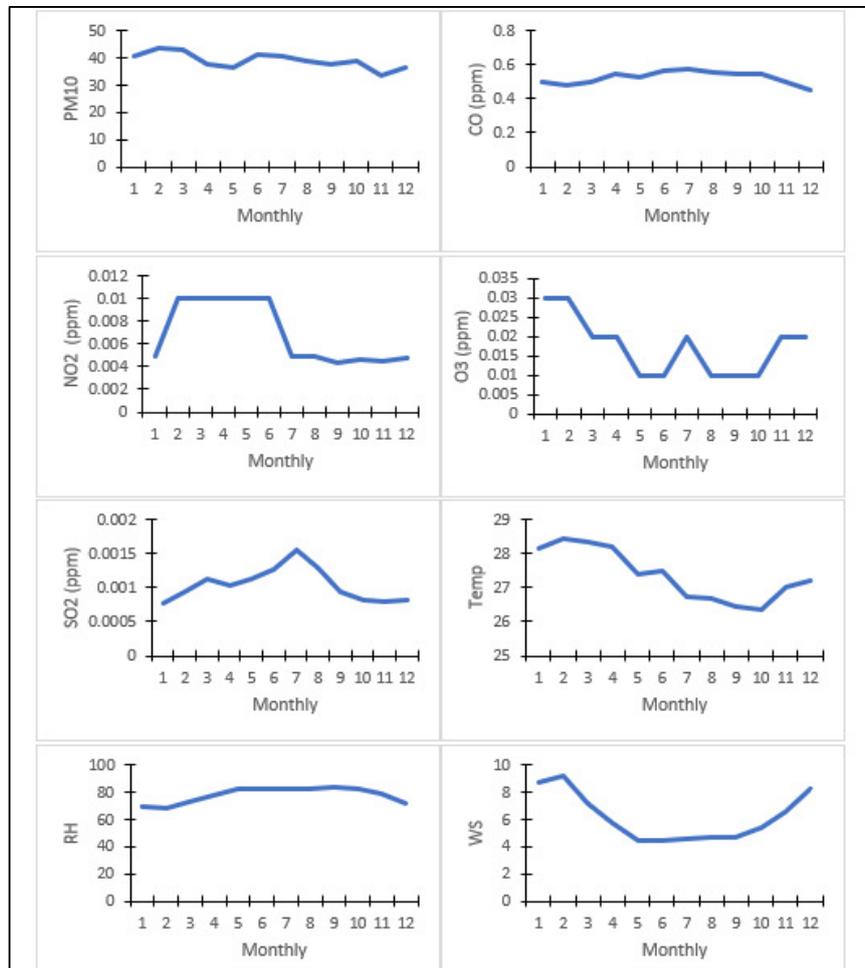
The compilation of air quality data at Langkawi Island are summarized in Table 2. Interestingly, PM<sub>10</sub> was found to be the most dominant air pollutant compared to others. The averaged concentration of PM<sub>10</sub> recorded was 39.26 µg/m<sup>3</sup> and it was below the MAAQG standard for the 24 hours concentration. CO was found to be the predominant air pollutant after PM<sub>10</sub> and followed by O<sub>3</sub>, NO<sub>2</sub> and SO<sub>2</sub> which had their average concentration at 0.525 ppm, 0.02 ppm, 0.005 ppm and 0.001 ppm. The averaged concentration of these air pollutants were also below the MAAQG standard limit as well.

**Table 2.** Overall data on air quality at Langkawi Island.

Parameters	Mean	Standard deviation	Min	Max	Skewness
PM <sub>10</sub> (µg/m <sup>3</sup> )	39.259	16.016	7.52	386.94	5.506
CO (ppm)	0.525	0.207	0	3.2050	1.238
NO <sub>2</sub> (ppm)	0.005	0.004	0	0.0677	2.269
SO <sub>2</sub> (ppm)	0.001	0.001	0	0.0118	2.020
O <sub>3</sub> (ppm)	0.02	0.014	0	0.147	0.949

Figure 2 shows that the long-term monthly records of PM<sub>10</sub> data. The emission of PM<sub>10</sub> was found higher in February to March and June to July. Such observations were plausible to the severe haze episodes originated from uncontrolled forest fires [12] in Indonesia particularly to 2005. The concentration of CO, SO<sub>2</sub> and NO<sub>2</sub> was due to the emissions of motor vehicles used by local as well as tourists. Meanwhile, the O<sub>3</sub> is formed from photochemical reactions of NO<sub>2</sub> that involved sunlight and heat [13].

The profile of relative humidity, CO and SO<sub>2</sub> possessed with similar pattern profiling throughout the years. For example, the increased in relative humidity would decreased the temperature of Langkawi Island from September to December because of the monsoon season.

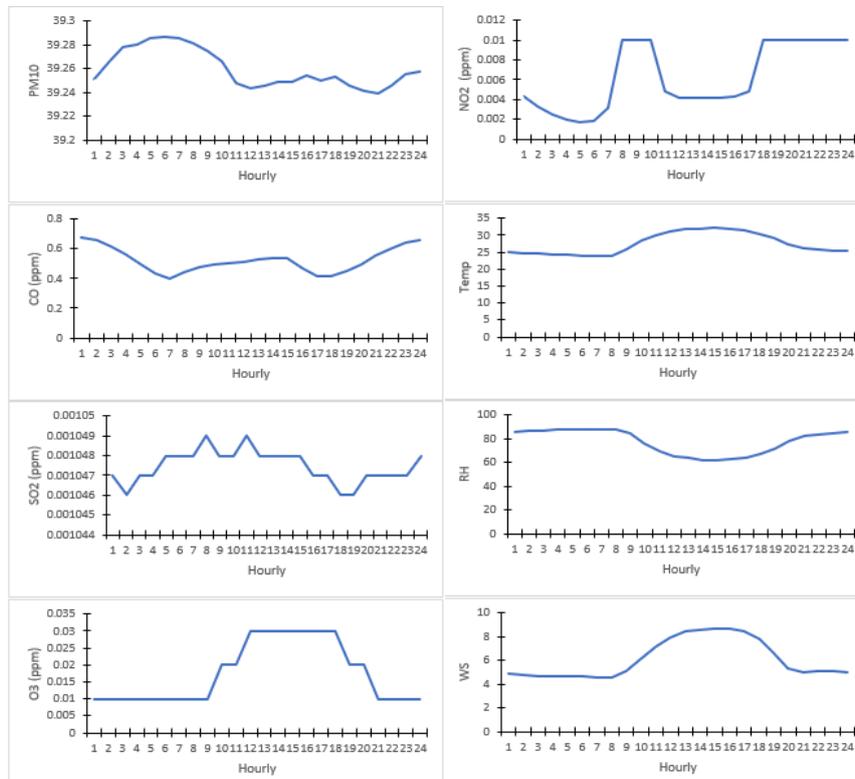


**Figure 2.** Monthly trends of air quality in Langkawi Island.

**3.2. Daily Trends**

Figure 3 shows the hourly air data quality of each pollutants in Langkawi Island. There was few peaks on each air pollutants' concentration within 24 hours trend. It is clearly exhibited that the concentration of PM<sub>10</sub>, NO<sub>2</sub> and SO<sub>2</sub> were increased from 7 am to 9 am. This observation can be attributed by traffic congestion as people were going out to work and children going to school during these hours. Similar pattern was observed in the evening session as well. There was small increased in concentration of PM<sub>10</sub> and NO<sub>2</sub> from 5 pm to 6 pm as people were going back from work and school. The concentration of O<sub>3</sub> were highest from 12 pm to 5 pm due to the hot weather and the existence of sunlight during the daylight. The concentration of NO<sub>2</sub> and SO<sub>2</sub> has the same pattern where it has an increased and decreased phase at specific time.

Uniquely, the meteorological factors such as temperature and wind speed possessed the same pattern of profiling where it increased slowly from 9 am and decreased slowly to 6 pm because of the sun's warming effect that directly influencing the increased in wind speed. On contrary, the relative humidity decreased with the increased in the temperature and wind speed.



**Figure 3:** Hourly trends for air quality in the Langkawi Island.

**3.3. Correlation between air pollutants and meteorological factors**

Table 3 shows detailed interaction and correlation between the air pollutants. Interestingly, all air pollutants have a positive correlation with each other. PM<sub>10</sub> has a positive low correlation with CO, NO<sub>2</sub>, SO<sub>2</sub> and O<sub>3</sub> which were (r = 0.283, p < 0.01), (r = 0.480, p < 0.01), (r = 0.070, p < 0.01) and (r = 0.215, p < 0.01), respectively. The correlation of PM<sub>10</sub> with O<sub>3</sub> became positive was due to the hot weather conditions that induced the formation of O<sub>3</sub> [14]. Although CO has a positive low correlation with NO<sub>2</sub> and SO<sub>2</sub> at (r = 0.166, p < 0.01) and (r = 0.144, p < 0.01), it also has a negative low correlation with O<sub>3</sub> (r = -0.120, p < 0.01). A negative relationship suggested the likely hydrocarbon oxidation which consumes O<sub>3</sub> and subsequently producing CO [15].

**Table 3:** Correlation between parameters.

Parameter	PM <sub>10</sub>	CO	NO <sub>2</sub>	SO <sub>2</sub>	O <sub>3</sub>
PM <sub>10</sub>	1				
CO	0.283**	1			
NO <sub>2</sub>	0.480**	0.166**	1		
SO <sub>2</sub>	0.070**	0.044**	0.008*	1	
O <sub>3</sub>	0.215**	-0.120**	-0.081**	-0.046**	1

\*\* . Correlation is significant at the 0.01 level (2-tailed).

\* . Correlation is significant at the 0.05 level (2-tailed).

Meteorological factors have a significant correlation with all the pollutants as presented in Table 4. PM<sub>10</sub> has a positive low correlation with temperature and wind speed with (r = 0.076, p < 0.01) and (r = 0.069, p < 0.01) while posed a negative low correlation with relative humidity (r = -0.119, p < 0.01).

High relative humidity caused the wash-out processes in the atmosphere according with the low numbers of rain occasions [16,17]. Therefore, there is a negative correlation between PM<sub>10</sub> and relative humidity. In addition, temperature also has a negative correlation with relative humidity ( $r = -0.748$ ,  $p < 0.01$ ) but has a positive linear correlation with wind speed ( $r = 0.411$ ,  $p < 0.01$ ). The wind speed correlation with PM<sub>10</sub> and temperature possessed positive low correlation at ( $r = 0.069$ ,  $p < 0.01$ ) and ( $r = 0.411$ ,  $p < 0.01$ ), respectively.

**Table 4:** Correlation between meteorological factors.

Parameter	PM <sub>10</sub>	T	RH	WS
PM <sub>10</sub>	1			
T	0.076**	1		
RH	-0.119**	-0.748**	1	
WS	0.069**	0.411**	-0.049**	1

\*\* . Correlation is significant at the 0.01 level (2-tailed).

#### 4. Conclusions

In conclusions, the average concentrations of air pollutants in Langkawi Island were still not exceed the standard limit of MAAQG. All the meteorological factors (temperature, relative humidity and wind speed) were significantly correlated with the concentrations of air pollutants. PM<sub>10</sub> turned out to be the dominant type of air pollutants in Langkawi Island which followed by CO, O<sub>3</sub>, NO<sub>2</sub> and SO<sub>2</sub> where the hot weather conditions contributed to such emission of PM<sub>10</sub> concentration. In addition, the wind speed and temperature influenced the distribution of PM<sub>10</sub> concentration within the vicinity due to south-west monsoon season. Such assessment's findings are imperative in protecting the human health as well as environment.

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