

PM₁₀ CONCENTRATIONS MEASUREMENTS IN THE ISLAND AND MAINLAND OF PULAU PINANG

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Gravimetric concentration of ambient particulate matter with aerodynamic diameter less than 10 μm (PM₁₀) are reported for four sites located in Penang state. Measurements in Penang island were carried over three 6 months period from 1st January 1998 to June 30th 1998, 1st January 2000 to June 30th 2000 and 1st January 2002 to 30th June 2002, whereas, measurements at Penang mainland site was made between 1st January and 30 June 2002 only. The PM₁₀ were measured using a tapered element oscillating microbalance (TEOM) PM₁₀ mass monitor for the first two measurement campaign in Penang Island and using Beta Attenuation (BAM) monitor for the third and fourth. Analysis of the ambient mass concentration data with reference to hourly and daily averages is presented. Results of the first six months in 1998 shows that the daily average PM₁₀ values range from a high of 9.7 $\mu\text{g m}^{-3}$ to 158.7 $\mu\text{g m}^{-3}$. Second six months of 2000 shows values range from 13.3 $\mu\text{g m}^{-3}$ to 63.0 $\mu\text{g m}^{-3}$. Third and fourth six months in Penang island and Penang mainland 2002 shows values range from 22.0 $\mu\text{g m}^{-3}$ to 131.0 $\mu\text{g m}^{-3}$, and 38 $\mu\text{g m}^{-3}$ to 141 $\mu\text{g m}^{-3}$. There were noticeable monthly and daily averages variations for the concentrations of PM₁₀ in ambient air in Penang state.

Introduction

Particulate matter (PM₁₀) have been highlighted since the last decade for causing adverse health effects (Schwartz, 1994; Dockery and Pope, 1994; Pope et al., 1995). Dockery and Pope, (1994) reported that for each 10 $\mu\text{g m}^{-3}$ increase in PM₁₀ concentration, there is an estimated increase of 0.6-1.6% in mortality.

Previous work on PM₁₀ and total suspended particulate (TSP) in Malaysia for example, Sham (1979), Azman (1984, 1987), Azman et al. (1987) and Latif et al. (2002) tended to concentrate within the Lembah Kelang and Langat Basin. These studies showed that PM₁₀ concentrations within these areas were below the annual Recommended Malaysia Guidelines (RMG) of 50 $\mu\text{g m}^{-3}$. However, in many instances the daily average RMG of 150 $\mu\text{g m}^{-3}$ were breached.

Not many reports are readily available reporting PM₁₀ levels for northern region of Peninsular Malaysia, especially in Penang. Ramli et al. (2002), and Ibrahim & Ramli (2002) have reported high air pollution levels in developing towns in North Perak. However, these studies concentrate on the traffic derived air pollution. Ramli and Ibrahim (2003) found that the ambient PM₁₀ trends at four sites with different backgrounds in Malaysia are generally good. This paper intends to study the PM₁₀ concentrations at Penang island sites and Penang mainland sites. The diurnal variations and monthly variations of PM₁₀ for this island are examined.

Continuous exposure to particulate pollution has long been associated with adverse health effects on human, especially those of respiratory related. More recent research, however, has shown a clear statistical connection between particulate matter pollution and daily mortality (Dept. of Health UK, 1995). However, the relationship is normally regarded secondary and selective on the basis that only sensitive groups were mostly affected. Most recent air pollution discourse has revealed that non-sensitive individual could turn sensitive depending upon his exposure to particulate pollutants. In recognition of these health effects, the United Kingdom Expert Panel on Air Quality Standards has recommended a limit on airborne particulate matter (PM_{10}) concentrations of $50 \mu g m^{-3}$ measured as a rolling 24 h average (EPAQS, 1995). This limit was further discussed and revised in 1999 to ensure better protection of human health (APEG, 1999).

In Malaysia, standards for air quality are not available. PM_{10} concentrations in ambient air in Malaysia are monitored based on Recommended Malaysian Guidelines (RMG) at a threshold of $150 \mu g m^{-3}$ for 24 h average and an annual means of $50 \mu g m^{-3}$ (DoE, 2000). Air pollution in Malaysia were reported in the form of index, which was introduced in 1996, to allow the general public to better understand the levels and action that should be taken should the air quality deteriorated to alarming level (Ramli, 2001).

Experimental

Air quality monitoring data from continuous air monitoring stations (CAMS) in Penang was gathered and collated. There are two CAMS in Penang Island, one measuring PM_{10} using Tapered Element Oscillating Microbalance (TEOM) method and another employing Beta Attenuation Method (BAM). Both methods are certified as Federal Equivalent Method (FEM) for measuring PM_{10} in the ambient air by the United State Environmental Protection Agencies (USEPA). Each data set contains hourly PM_{10} concentration data of January to June for the year 1998, 2000 and 2002. There were two sets of data for year 2002, one for at the island and another for mainland. These data were extrapolated to obtained daily average concentration (DAC) and monthly average concentration (MAC). High particulate pollution (when DAC above $150 \mu g m^{-3}$) episodes were carefully investigated and identified against the RMG.

Results and discussion

Hourly readings of a total of 180, 179, 178 and 181 samples of daily PM_{10} measurements were collected from the CAMS. Statistics for all valid observations of monthly PM_{10} average concentrations for 1998, 2000, 2002 (island) and 2002 (mainland) are presented in Table 1, 2 and 3, and 4, respectively. PM_{10} concentrations for the six months in 1998 ranges between minimum of $9.7 \mu g m^{-3}$ to maximum hourly average of $158.7 \mu g m^{-3}$. In 2000 the concentrations ranges between $13.3 \mu g m^{-3}$ and $63 \mu g m^{-3}$. The hourly PM_{10} concentrations were higher in 2002 (island) between $22-131 \mu g m^{-3}$. The hourly PM_{10} concentrations at the mainland were even higher ranging between $23 \mu g m^{-3}$ to $227 \mu g m^{-3}$. Daily average concentrations of PM_{10} for 2002 (mainland) were recorded between $47 \mu g m^{-3}$ to $92 \mu g m^{-3}$. For 2002 (island), the DAC recorded were between $23 \mu g m^{-3}$ to $93 \mu g m^{-3}$.

The monthly averages concentration in 1998 ranges between 28.2-43.7 $\mu\text{g m}^{-3}$, with the highest in March. The highest monthly average concentration in 2000 was in June at 33.9 $\mu\text{g m}^{-3}$. The PM_{10} monthly averages concentrations ranges between 22.8 $\mu\text{g m}^{-3}$ to 33.9 $\mu\text{g m}^{-3}$. Monthly PM_{10} average concentrations in 2002 at the island ranged between minimum 41.0 $\mu\text{g m}^{-3}$ to 64.1 $\mu\text{g m}^{-3}$. Highest monthly average was recorded in March 2002 at 64.1 $\mu\text{g m}^{-3}$. For 2002 (mainland), the monthly average concentrations ranged between 60 to 84 $\mu\text{g m}^{-3}$.

Table 1: PM_{10} Concentrations for Penang Island 1998

Month	Jan	Feb	March	April	May	June
Average	28.2	30.7	43.7	42.6	30.7	29.2
Maximum	43.2	43.6	158.7	61.0	50.5	50.5
Minimum	18.3	22.2	20.1	28.6	9.7	10.4
Std. Dev.	5.9	5.7	25.3	7.9	9.8	10.0

Table 2: PM_{10} Concentrations for Penang Island 2000

Month	Jan	Feb	March	April	May	June
Average	25.2	30.7	28.2	22.8	29.5	33.9
Maximum	41.2	48.6	41.0	33.5	63.0	46.9
Minimum	13.8	14.8	15.0	14.7	13.3	18.2
Std. Dev.	6.6	9.1	6.9	5.8	11.9	7.3

Table 3: PM_{10} Concentrations for Penang Island 2002

Month	Jan	Feb	March	April	May	June
Average	41.0	55.8	64.1	44.1	43.4	53.8
Maximum	65	82	131	120	79	105
Minimum	27	32	27	26	22	22
Std. Dev.	10.6	12.0	29.8	7.9	15.9	26.8

Table 4: PM_{10} Concentrations for Penang Mainland 2002

Month	Jan	Feb	March	April	May	June
Average	60	69	73	70	77	84
Maximum	88	82	125	97	123	141
Minimum	39	51	38	47	49	52
Std. Dev.	11	10	21	13	16	28

Figure 1, shows the trends of PM_{10} between January to June of 1998, 2000, 2002 (island) and 2002 (mainland). The daily average concentration of PM_{10} for Penang Island represents monitoring in 2002. Of note, the higher concentrations of PM_{10} recorded in this year compared to the two previous years. There are two possible explanations for this observation. First, the PM_{10} concentrations in 2002 were higher than 1998 and 2000, perhaps, due to the increase in emissions from local as well as transboundary sources. Secondly, the monitoring method used to measure PM_{10} concentrations in 1998 and 2000 was TEOM compared to BAM in 2002. TEOM instrument, although received certification from the USEPA, the measurement method has been a matter of debate

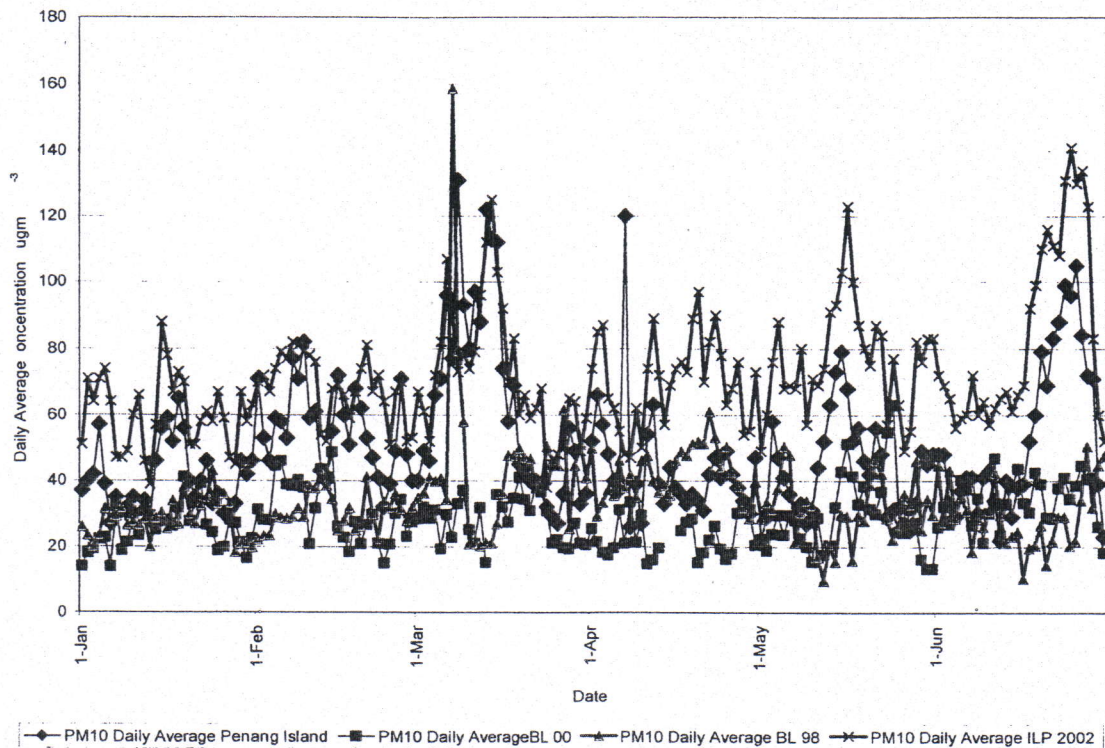


Figure 1: Comparisons between daily averages PM_{10} concentrations for six months in 1998, 2000 and 2002 in Penang Island and 2002 in Penang Mainland

Figure 1, shows the trends of PM_{10} between January to June of 1998, 2000, 2002 (island) and 2002 (mainland). The daily average concentration of PM_{10} for Penang Island represents monitoring in 2002. Of note, the higher concentrations of PM_{10} recorded in this year compared to the two previous years. There are two possible explanations for this observation. First, the PM_{10} concentrations in 2002 were higher than 1998 and 2000, perhaps, due to the increase in emissions from local as well as transboundary sources. Secondly, the monitoring method used to measure PM_{10} concentrations in 1998 and 2000 was TEOM compared to BAM in 2002. TEOM instrument, although received certification from the USEPA, the measurement method has been a matter of debate internationally. The fact that in TEOM, the sample inlet is heated at 50°C to eliminate problem with condensation tend to 'under-measure' the PM_{10} concentrations in ambient air. APEG (2000) and Ramli (2001) discuss this issue of possible error in detail. The corrected values for PM_{10} concentration using TEOM are discussed elsewhere.

DAC as well as MAC for Penang mainland site were higher than the island site. This indicated that the air quality in the island is better than at mainland. The mainland perhaps have more PM_{10} emitting sources and at higher rate as compared to island. Furthermore, air pollution dispersed better for an island environment, as compared to the mainland.

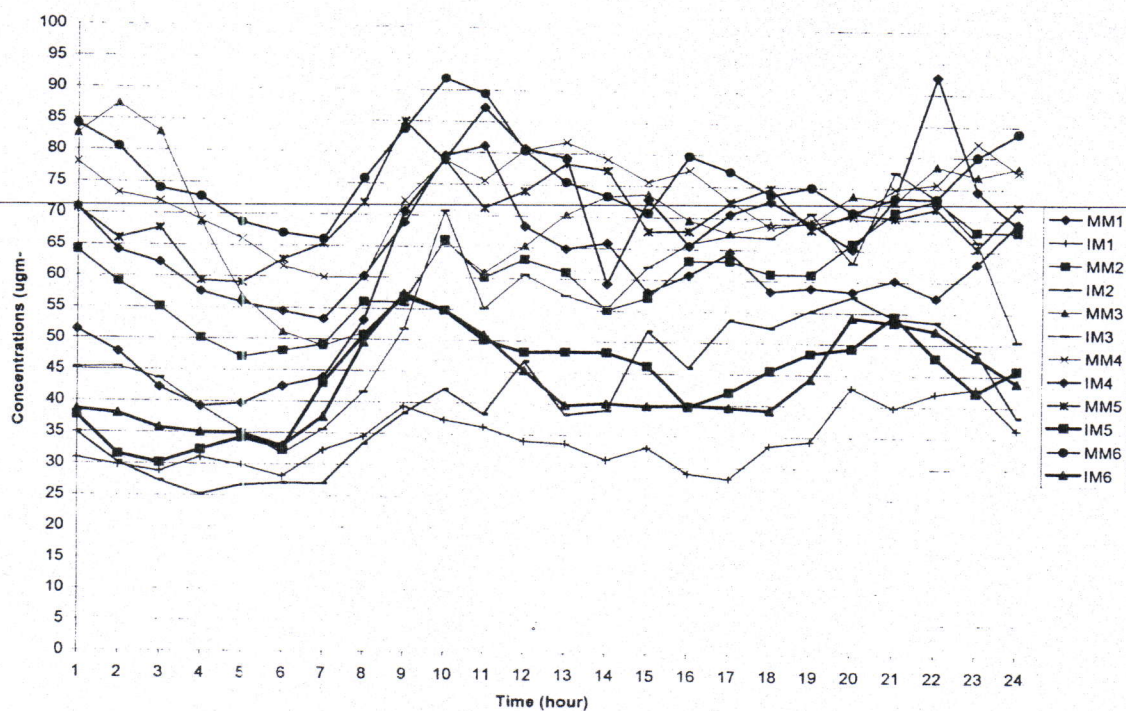


Figure 2: Diurnal variations on PM₁₀ concentrations January to June 2002 for mainland and island sites.

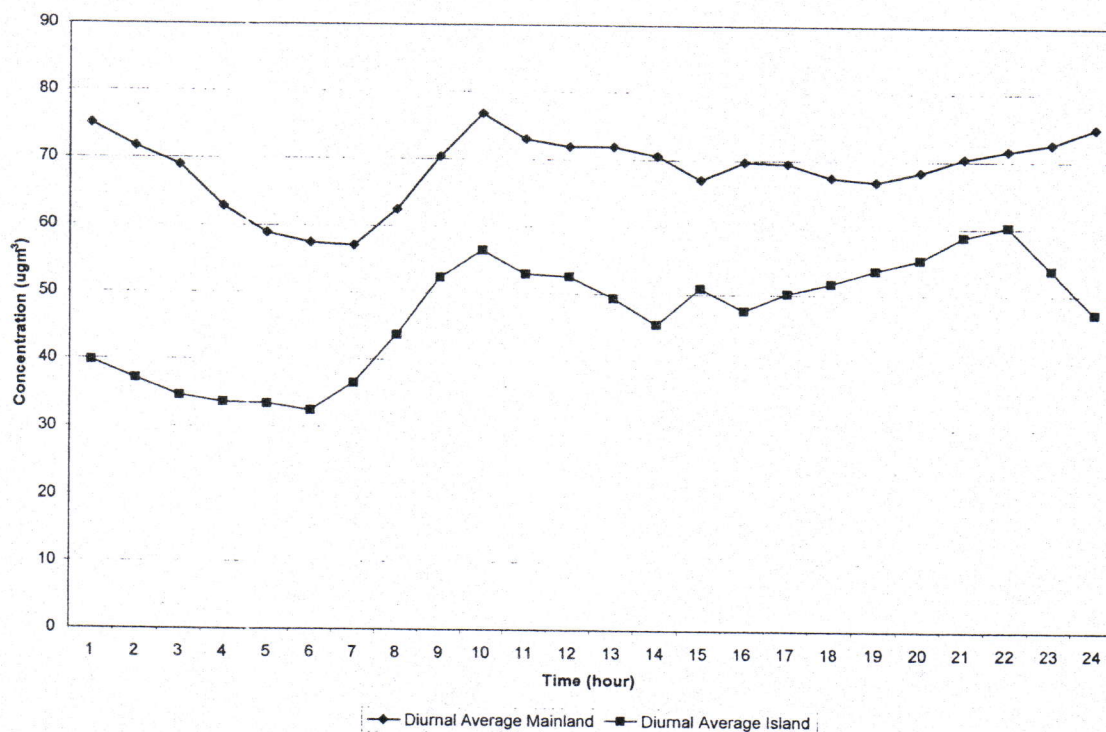


Figure 3: Comparative diurnal variations of PM₁₀ concentrations for mainland and island between January to June 2002.

The diurnal variations of PM₁₀ concentrations as shown in Figure 2 illustrate the 24 hours variations at both Penang island and mainland sites for six month in 2002. PM₁₀ diurnal variations for Penang Island shows that two 'major peaks' exist. The first 'major peak' (Figure 2) occurred between 7 a.m. and 10 a.m., followed by the first off-peak. A minor peak can be observed at approximately 1.00 p.m. and last for about an hour. Second 'major peak' conspicuously begin at 5.00 p.m. and extend up to 10 p.m. PM₁₀ concentrations during the second 'major peak', were higher than the first, in the morning. This trend is different from other diurnal studies that have been carried out in Malaysia, i.e. Ramli (2001), Ramli et al. (2001). Similar morning peak were observed in their studies, but evening peak tend to be lower and occur until up to 8 p.m..

Morning peak at the mainland sites occurred between 7 a.m. to 10 a.m., however, there are no clear peak occur after this as the hourly concentrations tend to persist at approximate concentration 70 $\mu\text{g m}^{-3}$. Perhaps the fact that an island has different microclimatic conditions as compared to mainland had contributed to this. There were multiple sources available from industries as well as vehicles that could have contributed to this trend. Perhaps, dispersion in island environment is better than in mainland. Finally there are perhaps more polluting processing in mainland compared to in the island of Penang state.

Conclusion

In this study we found that the levels of PM₁₀ concentrations been recorded in this study are well below the daily RMG of 150 $\mu\text{g m}^{-3}$ and annual RMG of 50 $\mu\text{g m}^{-3}$. Although, there were days that exceed the daily RMG, the numbers were relatively low. Fifteen out of twenty four month recorded PM₁₀ average concentrations below 50 $\mu\text{g m}^{-3}$. All monitoring for all sites showed that the PM₁₀ monthly average were below 100 $\mu\text{g m}^{-3}$ level. However, monitoring and manipulation of data from different year had suggested that PM₁₀ concentrations in Penang Island are rising. PM₁₀ concentrations in mainland were higher than in island. Further intensive investigations are required to identify and further control the source to ensure that the air quality in Penang could be sustained at good level.

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