Jurnal Teknologi, bil. 27, Dis. 1997 hlm. 61-67

ON THE FINE AND COARSE ATMOSPHERIC PARTICLE CONCENTRATIONS IN KUALA LUMPUR (1988-1990)

M. RASHID*
Department of Chemical Engineering
Universiti Teknologi Malaysia
80990 Johor Bahru.

A. RAHMALAN
Department of Chemistry
Universiti Teknologi Malaysia
80990 Johor Bahru.

Abstract. This paper presents some of the important findings on the atmopsheric fine, FP (particle with aerodynamic diameter, $d_a \leq 2.5$ µm) and coarse particles, CP (2.5 µm $\leq d_a \leq$ 10 µm) concentrations collected from July 1988 to December 1990 using a dichotomous sampler sited at the Universiti Teknologi Malaysia, Kuala Lumpur. Results showed that the mean FP and CP particle concentration was 35.4 and 14.2 µg/m3, respectively, with 40% of the daily total particle, TP (i.e TP = FP + CP) concentration samples exceeded the 50 µg/m3 annual mean guideline limit. On average, the FP constitutes 71% of the TP concentration measured at the site. Elevated particle concentrations were observed to be consistent with the frequency of calm conditions and wind direction which suggests that both were the important factors influencing the quality of air in the area.

Keyword: Air Pollution, particles, aerosols.

1 INTRODUCTION

Atmospheric aerosols can be characterized by both their elemental composition and size distribution. Whitby *et al.*[1] indicate that atmospheric particles fall into two distinct size classes; the fine and the coarse particles which are originated from different processes. The fine particles are usually associated with industrial source emissions as well as a result of chemical transformation of pollutants in the atmosphere. Whilst the coarse particle are those related to 'mechanically derived' aerosol such as from sea sprays and resuspension of soil material.

Rashid and Griffiths [2] studied on the trends of the fine and coarse atmospheric aerosol concentrations collected over a period of five years at the site. The authors concluded that the fine particulate mass concentration was twice the coarse concentration, and constituted up to 70% of the inhalable particulate (i.e fine+coarse) concentration during the study period. An increasing dominance of fine to coarse particulate concentration was also reported in the study. The limiting air pollution dispersion potential due to unfavourable meteorological conditions in the region was reported by Sham [3].

The present study is part of the results on the atmospheric fine and coarse particles concentrations measured from July 1988 to December 1990 at the air quality monitoring research station of the Universiti Teknologi Malaysia in Kuala Lumpur. The aim was to highlight some of the characteristics of the atmospheric particle concentrations in relation to the meteorological conditions of the area.

Typeset by SkoleXdex

2 METHODOLOGY

2.1 Sampling Site and Data Collection

A detailed description of the sampling site and the collection of the atmospheric particles has been given elsewhere [2] and is briefly described here. A total of daily 139 particles samples segregated into fine particle, FP ($d_a \leq 2.5$ μm) and coarse particle, CP (2.5 μm $\leq d_a \leq 10$ μm) were collected at the Universiti Teknologi Malaysia air quality research station in Kuala Lumpur. The samples were collected using a dichotomous sampler (Sierra Andersen, Model 244) which is designed to segregate the incoming particles into fine and coarse particles onto a separate filter collection media. The mass of the particle was determined gravimetrically on a CAHN 30 microbalance. The final particle concentration was obtained by dividing the mass of particle by the total volumetric flow rate of the air sampled.

2.2 Meteorological Parameters

The meteorological parameters reported in this paper were taken from the nearest meteorological station located in Petaling Jaya, *ca* 10 km southwest of the research station. These data were supplied by the Malaysian Meteorological Services.

3 RESULTS AND DISCUSSION

3.1 Particle Concentration

Table 1 presents the mean, standard deviation, and ranges of the particle concentrations as well as selected meteorological variables. The daily FP, CP and total particle, TP (TP = FP + CP) aerosol concentrations ranged from 12.2 μg m^{-3} to 164 μg m^{-3}, 3.06 μg m^{-3} to 32.6 μg m^{-3}, and 16.6 μg m^{-3} to 183 μg m^{-3} respectively. The fine particle concentration was as high as 164 μg m^{-3} on days of high pollution, which normally occur in July-August in the region. The overall mean of TP concentration was slightly above the annual Malaysian ambient air quality guideline for inhalable particulates (i.e particles with $d_a \leq 10$ μm) of 50 μg m^{-3}.

The cumulative frequencies of the daily particle concentrations, expressed as a percentage of the total number of daily samples, are shown in **Fig 1.** It indicates that the mean concentrations of FP, CP and TP particles were 35.4 μg m^{-3}, 14.2 μg m^{-3}, and 49.7 μg m^{-3} respectively. Fig.1. also shows that 10% of the FP particle concentration samples and 40% of the TP particle samples exceeded the Malaysian inhalable particulate annual guideline limit of 50 μg m^{-3} during the study period. In a previous study, Rashid and Griffiths [2] found that the inhalable particulate concentration has exceeded the annual guideline limit of 50 μg m^{-3} almost 50% of the sampling days at the site. This suggests that to comply with the air quality guidelines for inhalable particulates may prove difficult in the area. The rapid industrial growth in the region for the last decade certainly makes it difficult for the area to achieve the desired quality of air.

Table 2 presents the particle concentration and the percentage contributed by the fine particle fraction as monitored in the city of Kuala Lumpur reported from other studies [2, 4]. Table 2 clearly showed that the TP particle concentration consists predominantly of fine rather than coarse particle and the fine particle constitutes between 68% and 74% of the total concentration in the Kuala Lumpur area. In this study, the FP was found to constitute between 50 to 80% of the TP mass concentration collected at the site. A high degree of correlation ($r = 0.97$, $p = 0.0001$) between the FP and the TP particle concentrations confirms the preponderence of fine particles in the area. The low correlation ($r = 0.49$, $p = 0.0001$) between FP and CP concentrations indicates the difference in source and/or meteorological influence upon these different types of particle concentration. Fine particles are linked to high temperature processes related to industrial or vehicular emissions etc whilst the coarse result from resuspension of dust materials through construction etc into the atmosphere. A significant positive relationship between the two particle size fractions at the site could be caused by the valley which traps the particles for a considerable period of time under poor meteorological conditions. As pointed out by Sham [3], there is a high frequency of neutral, isothermal, and weak inversion conditions occurring in the early morning hours in the region. This could presumably support our finding.

3.2 Temporal Variability of Particle Concentration

Table 3 presents the monthly mean particle concentrations, their ranges and their coefficient of variation along with the amount of rainfall. The aerosols exhibited a mean monthly concentration variation from 17% to 70% during the study period. The highest monthly variation of the FP particle concentration was in August when unfavourable weather conditions are usually encountered. During the study the fine to coarse particle concentration ratio was as high as 9:1 in the worst period which can cause severe visibility impairment and health problems. The variability of the particle concentrations suggests the importance of the meteorological variables as well as the local air pollution sources in affecting the air quality at the site.

The highest monthly mean aerosol concentration was observed between January and March with a second peak occurring in July-August (Table 3), while the levels were observed to decrease in June and December. Chow and Lim (1984)[5], in their studies, observed that the maximum and minimum levels of particulate concentrations correspond respectively with the relatively dry and wet seasons experienced in the region. Wash-out by rainfall was the main explanation given for their findings. There was a decrease in mean particle concentration during rainy as opposed to non-rainy days during the study period. This suggests a scavenging effect of rainfall on particles. But it cannot be confirmed since no strong relationship between the particle concentrations and the amount of rainfall was found in this study. Although the rainfall could effectively remove particles from the atmosphere, the process is not fully understood.

Fig. 2. presents the hourly frequency of wind from NE, SE, SW, and NW quadrants (with respect to the site) together with the monthly frequency of calm (wind less than 0.2 m s^{-1}) during the study period. Generally, the high hourly frequency of wind from NE-NW quadrants corresponds with the northeast monsoon season from December to March. On the other hand, a high percentage of SE-SW winds are observed during the southwest monsoon period between June and September. There is a high frequency of calm between 26% and 40% suggesting that the region may be subjected to high air pollution. Indeed, Sham [3] found that the air pollution potential in this region was worse than that experienced in the Los Angeles Basin with its poor atmospheric dispersive capacity.

The monthly mean of TP (representing FP and CP particles) concentration and the hourly percentage frequency of calm are given in **Fig. 3** The fluctuation of particle concentration was consistent with the percentage of calm throughout the year except in November-December (early northeast monsoon period) when high winds are usually observed. In addition, a high percentage of winds (31% to 40%) coming from the NE+NW sector (where less number of industrial activities are found) causes the pollution concentration to be at its lowest. Similarly, the combination of NE+NW winds of the same percentage of occurance in June, although with a relatively low percentage of calm, causes the particle concentration to decrease.

In contrast, the high TP particle concentration observed in February and August corresponds with the high percentage of calm observed then. The percentage frequency of calm observed in February and August was 39.6% and 33.1% respectively. The high proportion of winds from SE+SW (where many industrial activities are located) with 40% and 41% in February and August respectively, could be connected with the increased pollution concentration in these months. The highest TP concentration recorded during the haze of August 1990 for example, resulted from a high percentage of calm (58%) with wind mainly from the SW quadrant. Thus, an increase in particle concentration in February and August, results from pollution transported from highly industrialized areas combined with predominantly calm wind conditions. These findings suggest that calm conditions and wind direction are important factors affecting the air quality at the site. A positive correlation of the fine aerosol concentrations (as fine aerosols are predominantly related to industrial emissions) with the number of hours of calm (r=0.16, p=0.054) and of SW wind direction (r = 0.19, p = 0.023) confirms these findings, even though the correlation coefficients are small.

4 CONCLUSION

Inhalable particle concentrations monitored from July 1988 to December 1990 at the Universiti Teknologi Malaysia Air Quality Monitoring Station in Kuala Lumpur suggest that the compliance with the Malaysian guideline annual limit of 50 μg m^{-3} may not easily be achieved. As reported in this study, a high percentage (i.e 40%) of the daily TP (i.e FP + CP) particle concentration were observed to exceed the limit imposed, and this would perhaps show the level set for such inhalable particulates may not be realistic for the country. In addition, a high percentage of FP particle concentration of between 50% and 80% in the TP particle in the area indicates that other source of fine particles such as from the photochemical activity could be important.

Elevated particle concentrations observed were consistent with the frequency of calm conditions and wind direction from the SW-SE quadrants where heavily industrialized areas are located. The frequency of calm condition and wind direction seem to be the two most important meteorological factors affecting air quality at the site. While these factors are beyond human control, the level of air pollution concentration can be minimized through integrated control of air pollution in the region.

5 ACKNOWLEDGEMENT

This work has been part of the research project funded by the Research and Consultancy Unit, Universiti Teknologi Malaysia (Project No. 95021)

REFERENCES

[1] Whitby, K. T., Husar, R.B., and Liu, B.Y.H. 1972. The aerosol size distribution of Los Angeles smog. *J. Colloid Interface Sci*. 39:177-204.

[2] Rashid, M., and Griffiths, R.F. 1995. Trends of atmospheric fine and coarse particulates in Kuala Lumpur, Malaysia (1986-1990). *Environ Technol*. **16**:25-34.

[3] Sham, S. 1979. Mixing depth, wind speed and air pollution potential in the Kuala Lumpur-Petaling Jaya area, Malaysia. *Malayan Nature J*. **32**:233-245.

[4] Azman, Z.A., Hayashi M., Inouye, R. 1988. The temporal patterns of air pollutants in the Klang Valley, Malaysia. *Bull. Nat. Res. Inst. Poll. & Res*. **17**:13-26.

[5] Chow, K.K., and Lim, J.K. 1984. Monitoring of suspended particulates in Petaling Jaya. In *Urbanization and Ecodevelopment-with special reference to Kuala Lumpur*. Institute of Advanced Studies, pp. 178-185. University of Malaya,.

Table 1. Mean, standard deviation, ranges of aerosol concentrations and selected meteorological variables in Kuala Lumpur (1988-1990)

Parameter	Mean	SD*	Ranges
FP (μg m^{-3})	35.5	16.4	12.2 - 164
CP (μg m^{-3})	14.2	5.91	3.06 - 32.6
TP (μg m^{-3})#	49.7	19.9	16.6 - 183
Rel. Humidity (%)	80.5	6.73	62.5 - 93.6
Temp. Ave (°C)	27.8	1.06	23.9 - 29.8
Temp. Max (°C)	32.6	1.41	26.5 - 35.6
Temp. Min (°C)	23.9	0.89	21.8 - 26.2
Rainfall (mm)	9.86	14.9	0.10 - 86.5
Solar Radiation (Mwhr cm^{-2})	440	104	124 - 651
Wind Speed (m s^{-1})	1.01	0.41	0.20 - 3.30

* SD = Standard Deviation
# TP = (FP + CP)

Table 2. Percentage of fine particles in the total particle concentration of Kuala Lumpur

Parameter	Rashid & Griffiths [2]	Azman et al.[4]	This work
FP (μg m^{-3})	36.1	43	35.5
CP (μg m^{-3})	16.7	15	14.2
TP (μg m^{-3})#	52.8	58	49.7
% FP/TP	68%	74%	71%

TP = FP + CP

Table 3 Monthly mean, range and the coefficient of variation of concentration and rainfall in Kuala Lumpur

Monthly	FP (μg m⁻³)				CP (μg m⁻³)				TP (μg m⁻³)				Rainfall (mm)			
	Mean	Min	Max	CV (%)	Mean	Min	Max	CV (%)	Mean	Min	Max	CV (%)	Mean	Min	Max	CV (%)
Jan	33.4	12.4	51.4	38.3	19.4	9.69	29.2	35.3	52.8	22.1	80.6	37.0	6.18	1.20	12.7	79.6
Feb	47.5	32.8	73.7	32.7	19.0	9.70	30.2	41.4	66.5	42.5	96.5	32.7	8.23	0.60	20.9	134
Mar	38.9	29.2	51.6	19.6	16.1	11.3	24.7	28.9	55.0	42.3	74.9	21.5	13.0	1.40	40.3	124
Apr	34.0	16.3	49.9	35.1	13.6	7.01	23.9	42.5	47.6	23.3	69.0	33.7	12.7	0.60	23.1	61.8
May	33.4	20.0	48.9	31.4	14.0	7.48	21.6	36.6	47.4	29.4	61.2	28.0	11.9	0.10	31.2	125
Jun	29.9	13.5	48.8	35.3	7.11	3.06	13.0	33.7	37.0	16.6	57.0	33.3	5.55	0.80	10.3	146
Jul	42.0	23.7	76.6	34.3	16.9	11.0	23.6	22.3	58.9	37.0	100	27.7	15.8	0.40	86.5	202
Aug	48.7	22.5	164	69.8	15.6	6.27	32.6	39.5	64.3	33.9	183	56.3	19.3	0.20	62.3	150
Sep	33.1	23.2	41.0	16.6	12.1	4.31	24.6	42.3	45.2	27.5	53.4	14.5	14.9	0.40	37.4	83.4
Oct	34.3	16.3	57.7	31.5	14.8	4.50	25.3	35.8	49.1	21.0	78.7	31.3	5.11	0.10	30.5	191
Nov	26.0	14.8	44.7	37.0	10.6	6.22	13.7	23.5	36.6	22.7	54.9	30.3	4.41	0.10	16.8	141
Dec	21.6	12.2	30.0	22.5	10.8	4.78	19.9	32.2	32.4	17.0	46.0	22.2	6.60	1.30	18.6	99.4

* TP = FP + CP

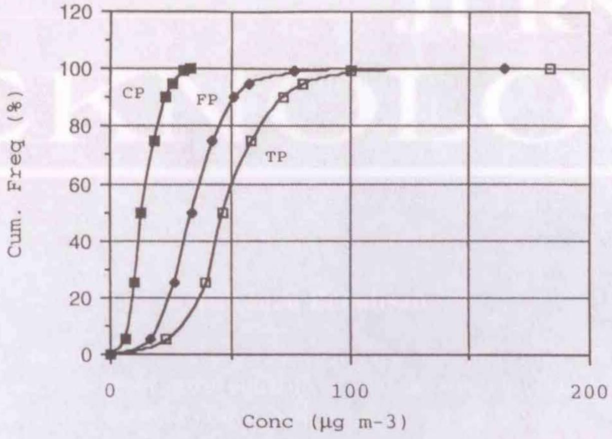

Figure 1 Cumulative frequency of aerosol concentration in Kuala Lumpur ('88 - '90).

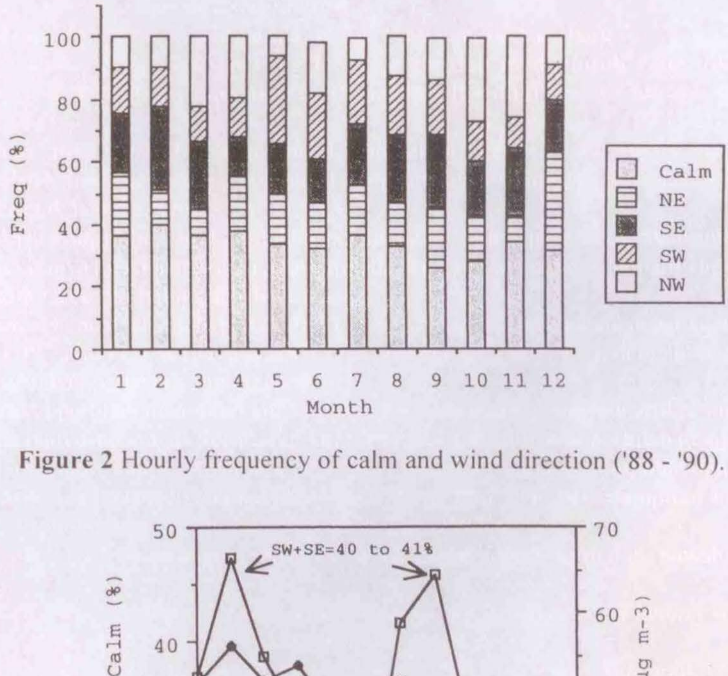

Figure 2 Hourly frequency of calm and wind direction ('88 - '90).

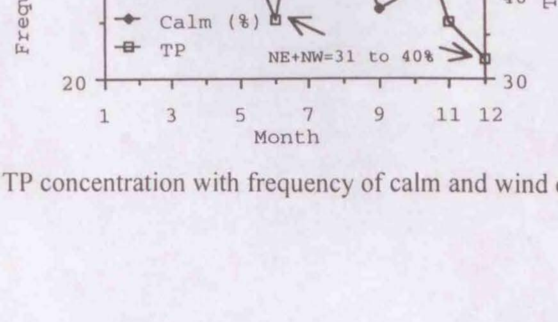

Figure 3 TP concentration with frequency of calm and wind direction.