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Investigation of Variations and Trends in TSP Concentrations in The Klang Valley Region, Malaysia

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ABSTRACT

Air pollution in the atmosphere by TSP is a problem that has been growing for the last few years due to rapid industrialization, population growth and urbanization in the Klang Valley Region. Suspended particle levels are monitored in ambient air quality network of their potential impact on human health, visibility and climate. The objective of this study is to investigate variations and trends in TSP in the Klang Valley Region and to identify the main factors affecting the variation in TSP concentrations. This analysis used daily data collected from Malaysian Meteorological Services for Petaing Jaya station monitoring TSP data for the period 1977-2002. On daily average basis, annual, seasonal, monthly and weekly variations and trends in TSP concentrations are presented. Linear regressions were performed of the annual average TSP over the 1977 through 2002. The slope of the regression line in annual average decreased in TSP in order of -0.977 and statistically significant at 0.05 level. This suggests that whatever control measures have been applied are effective in reducing TSP concentrations. TSP concentrations in the Klang Valley Region showed seasonal variation, with the higher concentration during southwest monsoon season (dry season) and lower concentrations during rainy season. The causes of highest TSP concentrations during southwest monsoon season due to lack of rainfall and the stable atmospheric conditions, which reduce the ability of atmosphere to disperse the pollutants. The weekly pattern of TSP concentration exhibits a downward trend from Tuesday (maximum) to Sunday (minimum). This weekly cycle in TSP gives the indication that the main sources of the particulates in this area are from human activities rather than natural sources.

ABSTRAK

Pencemaran udara oleh TSP di atmosfera merupakan suatu masalah yang telah bertambah dalam beberapa tahun yang lepas di Wilayah Lembah Klang disebabkan oleh perindustrian yang pesat, pertambahan penduduk dan pembandaran. Aras partikel terampai dicerap dalam rangkaian kualiti udara ambien tentang potensi impaknya terhadap kesihatan manusia, visibiliti dan iklim. Objektif kajian ini adalah untuk mengesan variasi dan tren TSP di

Wilayah Lembah Klang dan mengenal pasti faktor utama yang mempengaruhi variasi dalam kepekatan TSP. Analisis ini menggunakan data harian yang dikumpulkan di stesen Perkhidmatan Kajicuaca Malaysia di Petaling Jaya bagi data TSP untuk tempoh 1977-2002. Variasi dan tren tahunan, musiman, bulanan dan mingguan berasaskan purata harian kepekatan TSP dikemukakan. Regresi linear dilakukan terhadap purata tahunan TSP diantara 1977 hingga 2002. Cerun garis regresi dalam purata tahunan TSP menurun sebanyak -0.977 dan didapati signifikan pada aras 0.05. Keadaan ini mencadangkan bahawa walau apapun langkah kawalan yang telah dilaksanakan adalah berkesan dalam mengurangkan kepekatan TSP. Kepekatan TSP di Wilayah Lembah Klang menunjukkan variasi bermusim dengan kepekatan yang lebih tinggi semasa musim monsun barat daya (musim kering) dan kepekatan yang lebih rendah semasa musim hujan. Penyebab kepekatan TSP paling tinggi semasa musim monsun barat daya adalah kekurangan hujan dan keadaan atmosfera yang stabil yang mengurangkan keupayaan atmosfera menyelerakkan bahan cemar. Pola mingguan kepekatan TSP menunjukkan tren menurun dari hari Selasa (maksimum) ke hari Ahad (minimum). Kitar mingguan kepekatan TSP memberikan gambaran bahawa sumber utama partikel di kawasan ini adalah daripada aktiviti manusia dan bukannya semulajadi.

INTRODUCTION

Rapid urbanization and industrial growth within the Klang Valley Region has resulted in vast quantities of potentially harmful waste products being released into the atmosphere. Consequently, the region is experiencing many symptoms of environmental degradation such as air pollution and acid rain. The Klang Valley is considered the largest region of Malaysia concerning metropolitan area and population. Moreover, it has the fastest growing and most industrialized structure in the country.

The term "particulate" is used to mean any dispersed matter, solid or liquid, in which the individual aggregates are larger than single small molecules (about 0.0002 micron in diameters) but smaller than about 500 micron. Particulates include aerosols, fumes, dust, mist and soot. The particles of most interest lie between 0.1 micron and 10 micron in diameter. Particles smaller than 0.1 micron undergo random motion and through coagulation generally grow to size larger than 0.1 micron and particles larger than 10 micron settle quickly as dust (Sham 1980).

The monitoring of pollutants in the network has thus far been limited to using the concentrations of sulphur dioxide and suspended particulate matter as indicators of pollution in urban environments. In recent years, concern about particulate air pollution has increased (Chan et al. 2001).

Recent epidemiological studies indicated that particulate matter (PM) is believed to associate with serious public health risks including increased risk of morbidity and mortality due to respiratory illness, cardio-vascular disease and cancer (Schwartz et al. 1996). The main objective of this paper is to investigate variations and trends in TSP in the Klang Valley Region.

DATA AND METHODS

Air pollution monitoring TSP in Petaling Jaya started in 1974. The Petaling Jaya TSP monitoring are the longest established in the Malaysian Meteorological Services network. Daily TSP data collected from Malaysian Meteorological Services for Petaing Jaya station for the 1977-2002**.**

Trends were calculated in four different ways (i) from annual average (ii) from seasonal means, which is a common approach (iii) monthly mean (iv) weekly mean. The most common method of estimating trend significance, i.e. the t-test of the Pearson correlation coefficient, has been shown to be applicable to annual trends for all variables. Trends analysis for annual TSP used linear regression. The slope estimate is calculated to give an indication of the magnitude of the linear trend. Trends examined on a per station basis.

The Spearman and Daniel's test were used to identify linear trends $H_0 : \beta = 0$, where β is the slope parameter in the regression equation $y_i = \alpha + \beta X_i + e_i$, $i = 1,\ldots, y_i$ is the index, X_i is the year, and e_i is the error term. The results are derived from the analysis are of the form there is evidence that the yearly TSP variables have (increased, decreased, or not changed) over the period of time.

RESULTS

Annual Variation and Trend of TSP Concentrations

Figure 1 shows annual average TSP concentrations from 1977 through 2002. The figure shows an average TSP value of approximately 96.3 μg m^{-3} in 1977, which decreases to approximately 69.7 μg m^{-3} in 2002, for a reduction of 28% (1.1 per year). The lowest annual average of 62.1 μg m^{-3} was recorded in 1990, whereas the highest level was recorded in 1983 (116.8 μg m^{-3}) and the second maximum in 1997 (114.1 μg m^{-3}). Linear regressions were performed of the annual average over the 1977 through 2002. The slope of the regression line is an additional measure of the

annual trend in TSP. The slope of the regression line in annual average decreased in TSP in order of -0.977 and statistically significant at 0.05

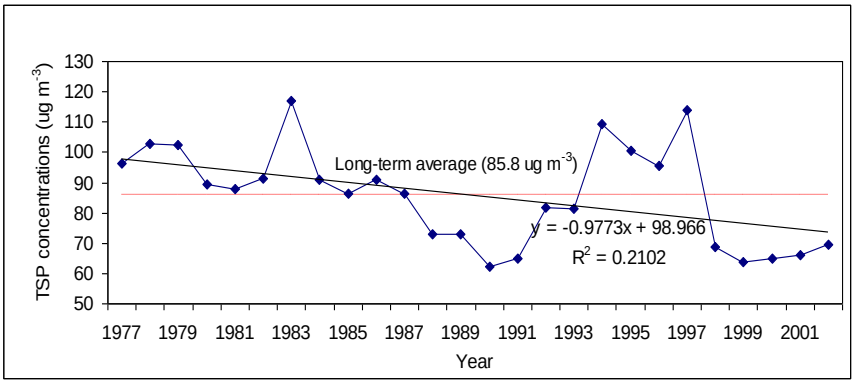

Figure 1. Annual mean and trends line of TSP concentrations (μg m^{-3}), Petaling Jaya, 1977-2002

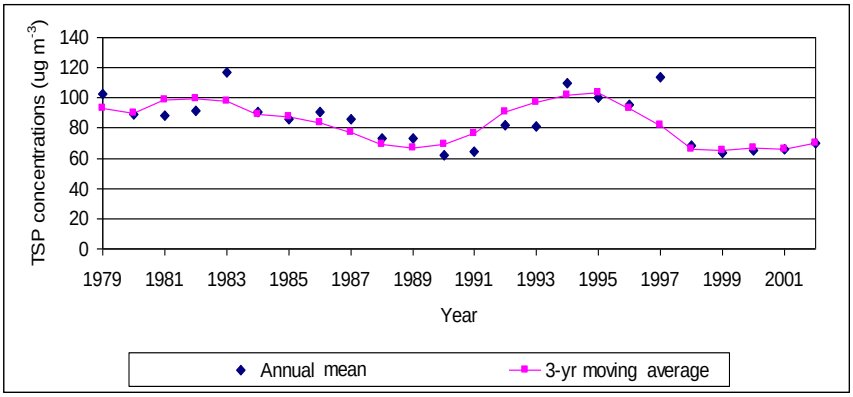

Figure 2. Three years moving average of the annual mean TSP concentrations (μg m^{-3}) at Petaling Jaya, 1979-2002

level. In order to get a clear trend in the TSP and to smoothen the inter-annual fluctuations, three year moving averages were computed and they are shown in Figure 2. The curve indicates that TSP concentrations have downward trend over the first two years from 1981 to 1982, showed a slight decrease from 1984 to 1990, and a sharp increase in 1990s until 1997 then decreased in 1998 onwards. A sharp increase was also observed during the 1990s, due to serious haze episodes in the Klang

Valley Region. Figure 3 shows the TSP trend of the 50th and 98th percentile over the 26-year time periods of 1977-2001. Using Daniel test, for $\alpha = 0.05$ and sample size n =26 the following results were obtained: t = -0.207 and -0.229 for 50th and 98th percentiles, respectively, t_N = 0.329, since $t < t_N$ for 50th and 98th percentiles, it can reject the null hypotheses H_o and it may be concluded that the downward trend is not significant at the 0.05 level of confidence.

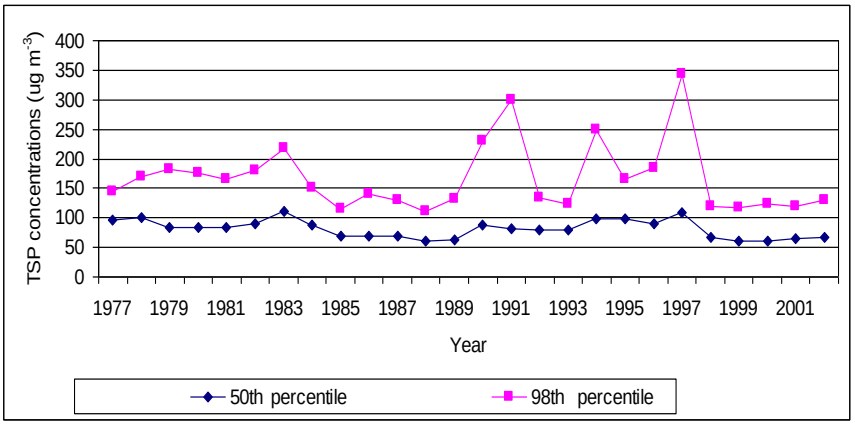

Figure 3. The 50th and 98th percentiles of annual mean TSP concentrations (μg m^{-3}) at Petaling Jaya, 1977-2002

Seasonal Variation and Trend of TSP Concentrations

The data was examined for seasonal trend, with the seasons defined as follows: northeast monsoon season (December-March); transitional monsoonal season (April-May), southwest monsoon season (June-September) and transitional monsoon season (October-November). Seasonal mean concentrations of TSP for Petaling Jaya for 1977-2002 are shown in Table 1. The TSP seasonal trend is also represented in Figure 4. Seasonal mean TSP concentration ranges from about 76.5 μg m^{-3} in transitional monsoon season (October-November) to 95.1 μg m^{-3} in southwest monsoon season. The seasonal TSP variation showed that the higher values occurred in southwest monsoon season than in northeast monsoon season and transitional seasons. This pattern is mainly linked to the great seasonal difference in rainfall. In northeast monsoon season, the higher averages of rainfall and then washout of particulate. While in southwest monsoon as dry season; hence low rainfall and then limits

washout of pollutants. The mean transitional monsoon seasons (April-May) and October-November) values are similar. TSP levels tended to be slightly higher in northeast monsoon season than in transitional monsoon seasons. It should be noted that the concentrations of TSP can be very different from day to day within the same season. Table 1 also gives the seasonal minimum, mean, maximum and standard deviation value for TSP. Southwest monsoon season showed the highest standard deviation (43.5) as well as the highest maximum, while transitional monsoon season (April-May) gives the lowest standard deviation (27.6).

Table 1. Seasonal mean concentrations (μg m^{-3}) ^{v}alue of TSP at Petaling Jaya for 1977- 2002

Season	Minimum	Mean	Maximum	SD
Northeast monsoon season	15.4	85.1	277.2	30.3
Inter monsoon season (April-May)	10.0	80.1	216.1	27.6
Southwest monsoon season	17.6	95.1	525.2	43.5
Inter monsoon season (Oct-Nov)	21.7	76.5	489.8	36.5

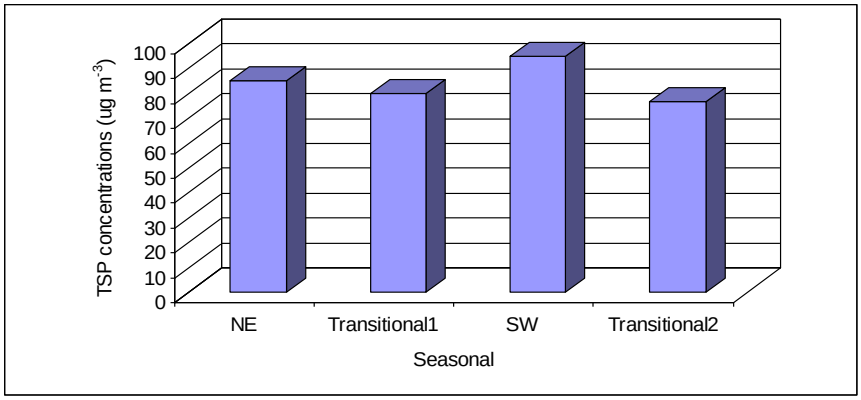

Figure 4. Seasonal mean total suspended particulate concentrations (μg m^{-3}) at Petaling Jaya, 1977-2002

Monthly Variation and Trend of TSP Concentrations

Monthly variations can more easily be observed by computing monthly average values from the individual 24-hour data. The monthly average results for TSP at Petaling Jaya presented in Figure 5. The highest monthly average of TSP was recorded in September 1997 (254.7 μg m^{-3}),

whereas the lowest value in November 2002 (55.2 μg m^{-3}) and December 2002 (55.6 μg m^{-3}). The results showed that TSP concentrations are relatively high and for 1997, there appeared to be no systematic variation in TSP concentration. The maximum TSP concentrations occur in the southwest monsoon season (June-September), with September 1997 being an exceptionally high month due to haze episodes.

On the other hand, lower TSP concentration, which fluctuate only slightly from month-to-month are observed during the rest of the year. In other words, the maximum occurring during the drier season, while the minimum during the wetter season. TSP showed an increasing trend from November in northeast monsoon season and higher concentration level in September in the southwest monsoon season. Generally speaking, results from this study demonstrate that for TSP concentrations level, a consistent variation with higher concentration level in the southwest monsoon months and lower level during northeast monsoon months and inter-monsoon months.

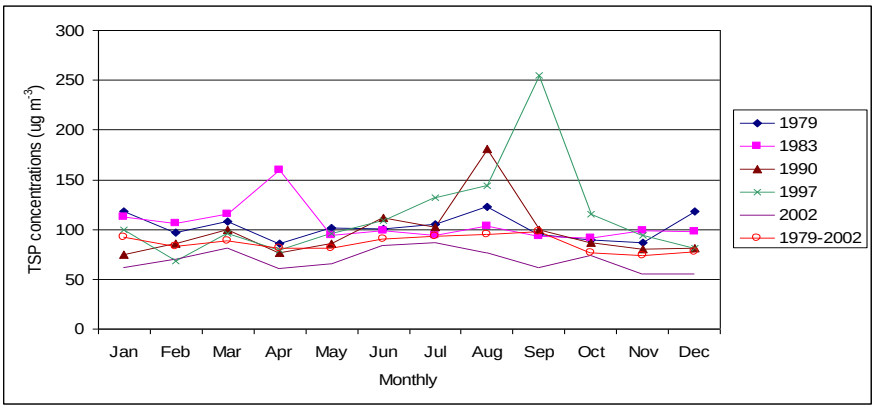

Figure 5. Monthly trends of TSP concentrations (μg m^{-3}) at Petaling Jaya 1979-2002

Weekly Variation of TSP Concentrations

Figure 6 displays the weekly trend of TSP over Petaling Jaya for the period 1983-2002. A common phenomenon is that the concentrations of TSP at weekdays are higher than that on Sunday. The highest values on Tuesday (79.8 μg m^{-3}) and the lowest on Sunday (62.9 μg m^{-3}). The value remained constant throughout the working days (Monday until Friday) followed by a relative decrease on Saturday (half day) and reaching its minimum value on Sunday (holiday). Some look very suggestive (such as

the monotonic increase from Monday to Friday in the 1983-2002 period). The weekly pattern exhibits a downward trend from Tuesday (maximum) to Sunday (minimum). The particulate concentrations have no significant difference from Monday to Saturday because the working week in Malaysia is five and half days. Furthermore, the traffic flow and industrial activity dropped during the non-working period. MMS (1995) reported earlier a significant reduction in TSP load can be observed with the normal shut-down of many industrial plants, construction activities and with less cars on the roads during the weekends.

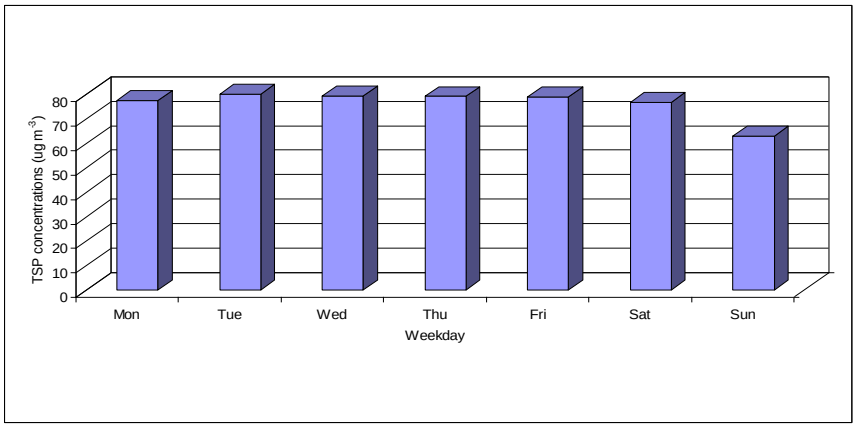

Figure 6. Weekly trend of TSP over Petaling Jaya for the period 1983-2002

DISCUSSION

The annual averages concentrations of TSP at Petaling Jaya during 1977-2002 showed that there are different between some of the years where there are some increases during 1977-1987 and 1993-1997 and the annual averages higher than the long-term average, while from 1988 to 1990 and 1998-2002 the annual average TSP concentrations below the long-term average. The annual averages of TSP shown in Figure 1, may provide some clue as to why 1983, 1994 and 1997 were the most polluted years during the period covered by this study. For the entire Petaling Jaya TSP levels were 18% and 16% higher in 1983 and 1997 than in 1977, due to serious haze episode in 1983 and 1997. Maximum TSP concentrations had been reached during haze episodes, during August-October 1994 and during August-October 1997. This suggests that during haze episodes the

average atmospheric dispersion conditions were the least favourable in terms of air pollution. Thus, TSP may therefore be an indicator for natural multiannual cycles occurring in the study area. The overall average rate of change in TSP (μg m^{-3} per year) during 1977-2002 is represented by the slope of linear regression was shown in Figure 1. It can be seen a clear downward trend in TSP levels (slope of -0.9773 μg m^{-3} per year). This suggests that whatever control measures have been applied are effective in reducing TSP concentrations. The variation in the peak values for each year quite high, although the variation appeared to be significantly reduced in the later 1998-2002 periods.

TSP concentrations were in the highest level during the southwest monsoon season, decreased through the northeast monsoon season, and tended to be the lowest during transitional monsoon season. The TSP concentrations during southwest monsoon season (95.1% μg m^{-3}) exceeding the long-term average 85.8 μg m^{-3} by 10%. The northeast monsoon season, transitional monsoon season (April-May) and transitional monsoon season (October-November) were 85.1, 80.1 and 76.5 μg m^{-3}, respectively.

In southwest monsoon season, when the weather relatively dry and relatively high winds are prevailing, emission from neighbour countries is brought to the Klang Valley Region especially during haze episodes in 1990s. In addition to the pollutant transport, together with the one omitted from local sources, tended to favour the accumulation of particulate in the Klang Valley Region. The stability of the weather conditions and the ability to disperse, are the factors that profoundly influence the air quality of urban areas of the Klang Valley Region. Besides the winds, the pollution concentration level is also affected by rainfall and relative humidity. The rainfall was scarce in the Klang Valley during southwest monsoon season and only low intensity rainfall occurred in Klang Valley Region during this period. Similar sequences of changes in atmospheric circulation explained the high concentration TSP in southwest monsoon season, suggesting that the monsoon circulation is responsible for the high concentrations in the Klang Valley Region in the southwest monsoon season beside emission from the source. Therefore, the highest concentrations in TSP during southwest monsoon season as dry season were most likely due to a combination of increased emissions from sources with lack of rainfall that limits washout.

The lack of precipitation during southwest monsoon season likely supported the build-up of pollution. On the other hand, the rainfall during northeast monsoon season could have reduced the build up of pollutants to some extent. Significant amounts of precipitation occurred

in early northeast monsoon and transitional monsoon seasons, which resulted in the cleansing of the atmosphere, therefore the concentrations of TSP dropped and remained relatively lower. Precipitation of considerable intensity also occurred in transitional monsoon season and also it was more effective in cleansing the air of pollutants.

This monthly variation in TSP gives some indications of a seasonal cycle with higher values occurring during the months of dry seasons and lower concentrations during rainy season. It should be observed that the maximum TSP has occurred in September 1997 during southwest monsoon (254.7 μg m^{-3}) whereas the minimum during November and December 2002 during inter-monsoon and northeast monsoon seasons, respectively. The TSP concentration suggests that some reduction in TSP levels occur during inter-monsoon months and northeast monsoon months, perhaps due to rain washout. The peak of TSP concentrations occurred in August and September during southwest monsoon season when the weather is dry and rainfall was scare during this period.

Overall, the monthly values were above1979-2002 mean values, except during 2002, which TSP loads below the period 1979-2002 mean value. TSP level does not fluctuate substantially during the year, except for August and September. High levels of TSP occurred in August and September were attributed to both the drier period and the haze episodes. The results show that during the period 1990-1997 the TSP concentrations were higher than the 1979-2002 mean value. This might be attributed to haze episodes in the 1990s.

TSP weekly variation showed the maximum on Tuesday (79.8 μg m^{-3}) and the secondary maximum on Wednesday (79.2 μg m^{-3}) (workdays), while the minimum on Sunday (62.9 μg m^{-3}) (holiday) due to lower industrial and commercial activities. This weekly cycle in TSP gives the indications that the main sources of the particulates in this area are from human activities rather than from natural sources. This was also reported by the MMS. A significant reduction in TSP load can be observed with the normal shutdown of many industrial plants, construction activities and with fewer cars on the roads during the weekends (Malaysian Meteorological Services 1995).

Lim and Leong (1991), reported that such a trend was attributed to the fact that certain establishments like schools and multinational companies are closed on Sunday, and most other offices are working only for half a day on Saturday. The increasing trend during the working days could mean that the daily TSP input into the atmosphere during a working day is always more than the amount removed. Moreover, there is large commercial, industrial and financial centres in Klang Valley Region

where people rush to work during the working days. Also, the traffic flow is relatively low on Sunday and holidays. Thus the TSP concentration levels in Petaling Jaya in weekdays are significantly higher than that on Sunday. The large difference in TSP concentration between workdays and weekends due to human activities such as road traffic, construction work, industrial processes which are generally higher during workdays.

This results are consistent with previous study findings carried out in the Klang Valley region by Sulieman (1997) and Yassen (2000), in Kuala Lumpur and Petaling Jaya, who found the concentration of TSP on weekdays are higher than on Sunday. In addition to that the Malaysian Meteorological Service conducted study on air quality in Malaysia for the year 1994 at four stations in Malaysia; namely: Petaling Jaya, Perai, Kuantan and Tanah Rata for 1994. The results showed that the first three stations had the same increasing trend from Monday and reaching it's a maximum on Monday and then dropped on Saturday and reached it's a minimum value on Sunday. On the other hand, TSP weekly trend was not noticeable in Tanah Rata station because it is located in a rural area, where the TSP values remained constant throughout the week.

CONCLUSIONS

This research investigates variations and trends in TSP concentrations in the Klang Valley Region and to identify the main factors affecting the variation in TSP concentrations. On daily average basis, annual, seasonal, monthly, weekly and daily variations and trends in TSP concentrations are presented.

Linear regressions were performed of the annual average TSP over the 1977 through 2002. The slope of the regression line in annual average decreased in TSP in order of -0.977 and statistically significant at 0.05 level. This suggests that whatever control measures have been applied are effective in reducing TSP concentrations.

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