Akademika 49 (Julai) 1996: 83 - 93

Relationships between Visibility and Selected Air Pollutants in the Klang Valley

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ABSTRAK

Keadaan berjerebu di Lembah Klang yang kali akhirnya berlaku pada Oktober 1991, mula muncul kembali pada Ogos 1994. Kajian ini yang dilakukan semasa permulaan episod jerebu tersebut, merupakan usaha awal untuk mengenal pasti jenis pencemar udara yang paling berhubungan dengan pengurangan visibiliti. Data visibiliti dan hujan telah diperolehi daripada Stesen Kajicuaca Lapangan Terbang Subang. Aras pencemar udara tertentu yang termasuk habuk ternafas (PM10), nitrogen oksida, nitrogen dioksida, sulfur dioksida, karbon monoksida dan ozon telah diukur dari sebuah stesen yang terletak di Dewan Bandaraya Kuala Lumpur. Data visibiliti, hujan dan pencemar udara telah dikumpul dari 1 Ogos hingga 4 September 1994, berjumlah 35 hari pensampelan selama 24 jam. Pada 2 dari 4 hari yang mempunyai visibiliti yang buruk, Panduan Kualiti Udara Malaysia untuk PM10, nitrogen dioksida dan sulfur dioksida telah dilampaui. Analisis Korelasi Pearson menunjukkan korelasi songsang yang bererti secara statistik antara visibiliti dengan PM10, nitrogen oksida, nitrogen dioksida dan karbon monoksida. Ini menunjukan pencemar daripada kenderaan bermotor serta punca pembakaran tempatan yang lain sebagai penyumbang penting kepada pengurangan visibiliti. Korelasi songsang yang bererti secara statistik di antara visibiliti dengan hujan juga menunjukkan ketidakkeberkesanan hujan renyai dalam dispersi jerebu. Kajian ini mengambil kesimpulan bahawa visibiliti di Lembah Klang mungkin semakin merosot dari tahun ke tahun; bahawa punca pencemaran udara tempatan mungkin memainkan peranan yang lebih penting dalam pengurangan visibiliti dan masalah jerebu, daripada apa yang dijangkakan; dan PM10 di atmosfera boleh mencapai aras yang tidak sihat pada ketika tertentu. Perbandingan dengan kajian-kajian lain mengukuhkan kesimpulan ini.

ABSTRACT

Hazy conditions over the Klang Valley which last appeared in October 1991, began to reappear in August 1994. This study which was conducted during the beginning period of the haze episode, represents a preliminary attempt to identify the types of air pollutants that may be most associated with visibility reduction. Visibility and rainfall data were obtained from the Subang Airport Meteorological Station. The levels of selected air pollutants which include respirable particulates (PM10), nitrogen oxide, nitrogen dioxide, sulfur dioxide, carbon monoxide and ozone were measured from a station located at Dewan Bandaraya Kuala Lumpur. Data for visibility, rainfall and air pollutants were collected from August 1 to September 4, 1994, giving a total of 35 24-hour sampling days. On 2 of the 4 days with poor visibility, the Recommended Malaysian Air Quality Guidelines for PM10, nitrogen dioxide and sulfur dioxide were exceeded. Pearson correlation analysis showed statistically significant inverse correlations between visibility and PM10, nitrogen oxide, nitrogen dioxide and carbon monoxide, indicating pollutants from motor vehicles and other local combustion sources as important contributors to visibility reduction. A statistically significant inverse correlation between visibility and rainfall also indicates the ineffectiveness of light rain in dispersing the haze. This study concludes that visibility in the Klang Valley may be worsening over the years; that local air pollution sources may play a much more important role in visibility reduction and the haze problem, than what might be realised; and that atmospheric PM10 may reach unhealthy levels at times. Comparison with other studies strongly support these conclusions.

INTRODUCTION

Visibility is the greatest horizontal visual range which is attained or surpassed throughout half the horizon circle, not necessarily continuous. Visual range is simply the maximum distance one may see in a given direction at a given time. In other words, visibility is the average visual range for all directions. Haze is the layman's term referring to the condition associated with reduced visibility due to the presence of excessive air pollutants in the atmosphere. Haze last appeared in the atmosphere over the Klang Valley in October 1991. The years of 1992 and 1993 were relatively haze-free. In 1994, hazy condition once again reappeared in August and September.

Reduction in visibility associated with haze is caused by two forms of interferences in light transmission in the atmosphere, namely light scattering and absorption by gases and particulates. Light scattering involves the interaction of light or electromagnetic radiation with gases or particulates in such a manner that the direction or frequency of the light is altered. Light absorption occurs when the electromagnetic radiation interact with gases or particulates and a proportion of that energy is transfered internally to the gas or particulate (Stern et al. 1984; Friedlander 1977 & Horvath 1993).

Since reduction in visibility is the result of complex interactions between various gaseous and particulate pollutants (Jamal & Zailina 1994 and Stern et al. 1984), there is a need to identify key pollutants which may be most associated with visibility reduction. This represents the main objective of this study. The identified key pollutants will give us an indication of the sources that may be implicated as contributors to the haze phenomenon. This study will hopefully be the first of a series of studies to describe and explain the haze phenomenon which has become a common feature of the Klang Valley.

METHODOLOGY

Data on visibility, rainfall and selected air pollutants were collected for this preliminary study. Visibility and rainfall data as measured at the Subang Airport Meteorological Station were obtained from the Malaysian Meteorological Services. Data on selected air pollutants, namely respirable particulates (PM10), nitrogen oxide (NO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO) and ozone (O_3), were measured in-situ from a sampling station at Dewan Bandaraya Kuala Lumpur (DBKL), operated by Universiti Putra Malaysia and the Department of Environment. It should be pointed out here that visibility and rainfall data were from a different sampling site than that for the air pollutant data. However, both the Subang Airport Meteorological Station as well as the DBKL air pollution station should generally be representative of the Klang Valley area to render meaningful comparison of the data.

RESULTS

Table 1 gives the descriptive statistics on the various environmental variables monitored at the DBKL station. Poor visibility (less than 5 km) was experienced on 4 of the 35 days (11.4%). The lowest visibility of 3.2 km was recorded on August 23, while the other 3 days were September 2 (4.7 km), September 3 (3.4 km) and September 4 (3.5 km). Visibility was moderate (5 to 10 km) on 9 of the 35 days (25.7%), while it was good (more than 10 km) on 22 of the 35 days (62.9%). Therefore, the range of

TABLE 1. Descriptive statistics on environmental variables monitored at Dewan Bandaraya Kuala Lumpur station, August and September 1994 (N = 35)

Variables	Minimum	Maximum	Mean	Std. dev.
Visibility (km)	3.20	14.80	10.31	3.27
PM10 ($\mu g/m^3$)	33.00	180.00	82.23	30.29
NO (ppb)	19.0	232.0	69.4	33.9
NO_2 (ppb)	15.0	56.0	25.7	7.2
NOx (ppb)	36.0	289.0	95.3	39.8
SO_2 (ppb)	3.00	56.0	6.9	8.7
CO (ppm)	1.3	3.8	2.6	0.5
O_3 (ppb)	3.0	20.0	10.9	4.1
Rainfall (mm)	0	1.0	0.1	0.2

visibility data from poor to moderate to good as shown by Figure 1 is suitable for the purpose of this study.

The maximum levels of CO (3.8 ppm) and O_3 (20 ppb) recorded are below the Recommended Malaysian Air Quality Guidelines (RMAQG) of 9 ppm and 60 ppb, respectively. However, these guidelines are for 8-hour mean values instead of the 24-hour mean values determined in this study. The guideline for PM10 of 150 $\mu g/m^3$ (24 hour) was exceeded twice on September 3 and 4. The guideline for NO_2 of 170 ppb (1-hour) was

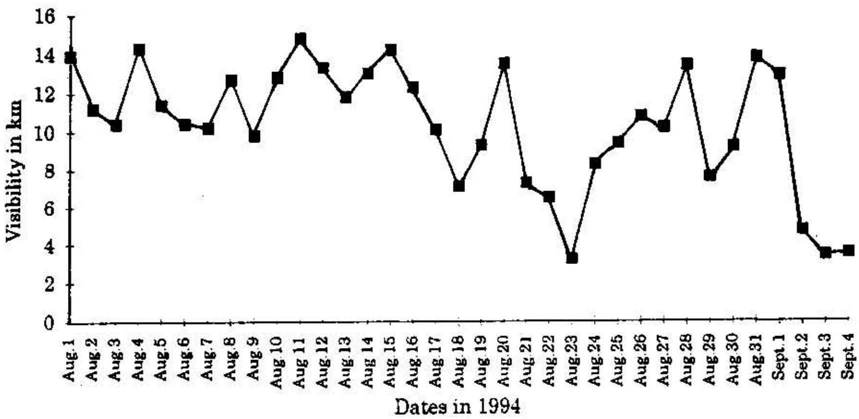

FIGURE 1. Visibility at the Subang Airport Meteorological Station in August and September 1994.

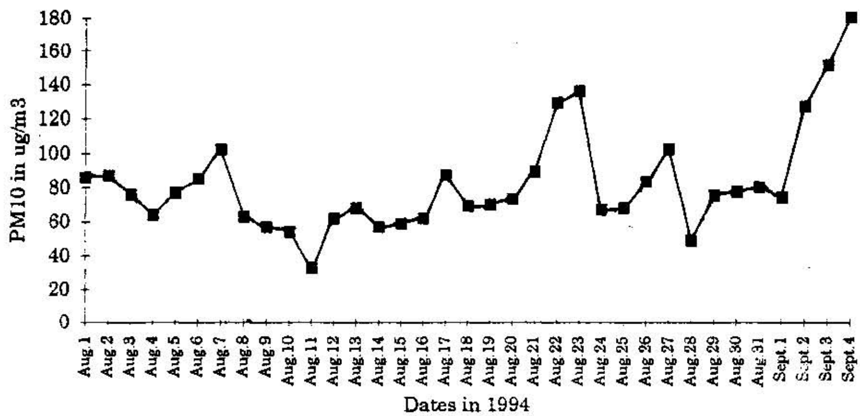

FIGURE 2. Atmospheric concentrations of respirable particulates (PM10) at Dewan Bandaraya Kuala Lumpur, August and September 1994.

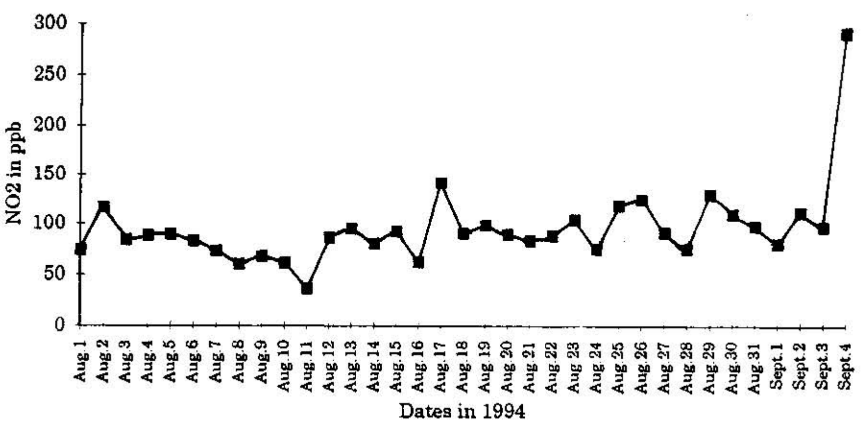

FIGURE 3. Atmospheric concentrations of nitrogen dioxide at Dewan Bandaraya Kuala Lumpur, August and September 1994.

exceeded only once on September 4. Again, this is a 1-hour mean value as compared to the 24-hour mean value used in this study. The guideline for SO_2 of 40 ppb (24-hour) was exceeded only once on September 4. The distributions of PM10 and NO_2 concentrations in the atmosphere are shown by Figures 2 and 3, respectively.

Tables 2 shows the result of Pearson correlation analysis between visibility and air pollutants as well as rainfall. Using the t-test analysis on

TABLE 2. Pearson correlations between visibility and selected air pollutants and rainfall in Klang Valley, August and September 1994

Pearson correlation between visibility and selected variables (N = 35)		
Variable	r value	p value
PM10 ($\mu g/m^3$)	− 0.80	0.0001*
NO (ppb)	− 0.46	0.005*
NO_2 (ppb)	− 0.62	0.0001*
NOx (ppb)	− 0.51	0.002*
SO_2 (ppb)	− 0.32	0.06
CO (ppm)	− 0.41	0.01*
O_3 (ppb)	− 0.13	0.47
Rainfall (mm)	− 0.35	0.04*

* Statistically significant t-test ($p < 0.05$).

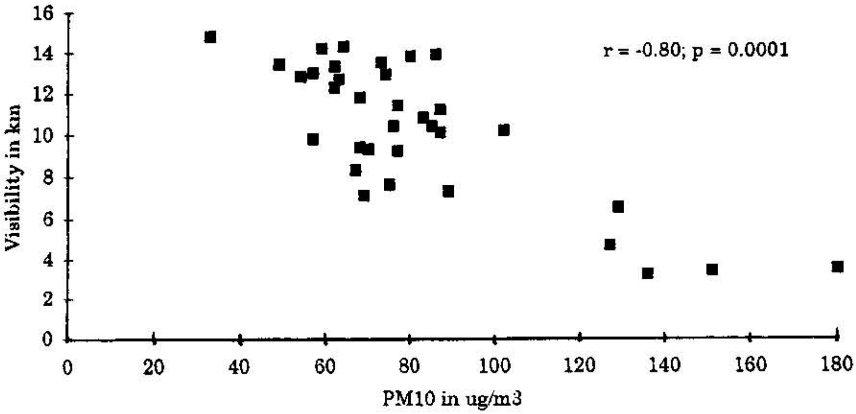

FIGURE 4. Relationship between visibility and respirable particulates (PM10) in Klang Valley, August and September 1994.

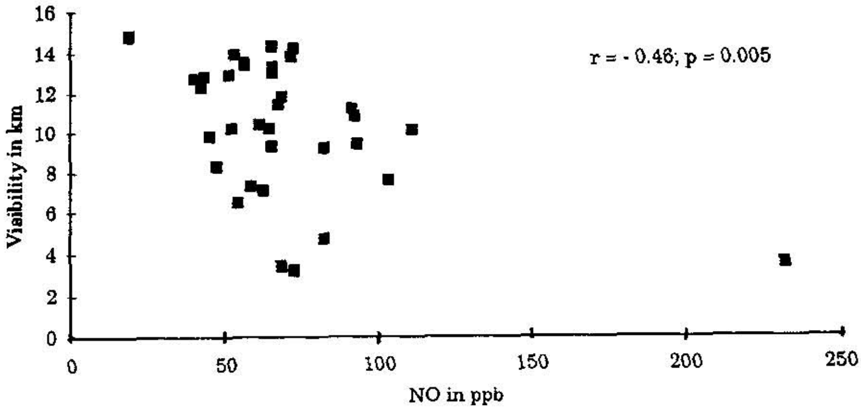

FIGURE 5. Relationship between visibility and NO in Klang Valley, August and September 1994.

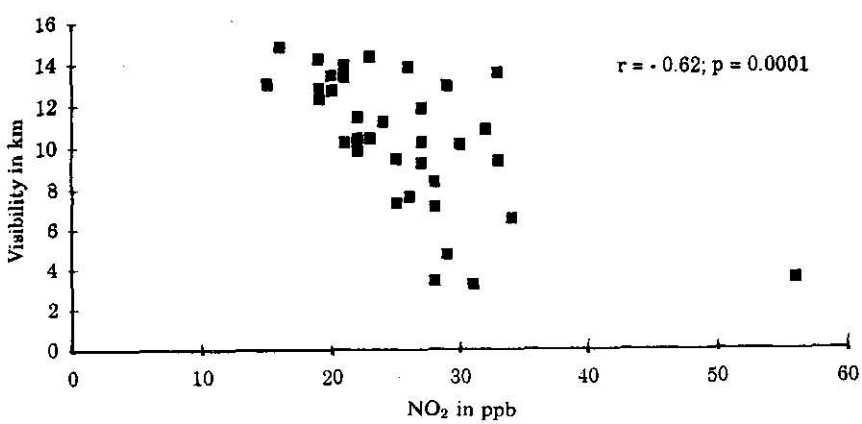

FIGURE 6. Relationship between visibility and NO_2 in Klang Valley, August and September 1994.

the coefficient of correlation (r values), statistically significant inverse correlations are found between visibility and PM10, NO, NO_2, NOx, CO and rainfall. The correlation between visibility and PM10, NO and NO_2 are also shown graphically in Figures 4 through 6, respectively.

DISCUSSIONS

Sham (1979) reported on the impact of urbanization and industrial development on visibility around Kuala Lumpur and Petaling Jaya during the period 1966 – 75. This study indicated that more than 70% of visibility occurences are in the range of 24 to 30.4 km. This range of visibility is more than twice the maximum visibility of 14.8 km recorded in this study. This may be an indication that visibility in the Klang Valley may have further worsen since then due to the increasing rate of urban development.

On 2 of the 4 days with poor visibility, September 3 and 4, the RMAQG for PM10, NO_2, and SO_2 was exceeded. PM10 include particulates having diameters of 0.1 to 1.0 μm which are mainly responsible for visibility reduction in the atmosphere by interfering with light transmission through absorption and scattering processes. NO_2 can also affects visibility through light absorption. Eventhough SO_2 does not by itself affect visibility, it will form sulfate particulates which affect visibility, through the process known as gas-to-particle conversion (Husar & Wilson 1993; Jamal & Zailina 1994).

The Pearson correlations analysis clearly indicate that visibility is reduced with increase PM10, NO, NO_2 and CO. All these pollutants, especially NO, NO_2, and CO are mainly from motor vehicles sources, even though they may also originate from any other combustion processes. PM10 may come from motor vehicles as well as other local pollution sources. According to a study conducted in 1992, motor vehicles contributed 66% of the NO_x load for the Klang Valley, followed by electric power stations (24%). General factories (56%) and motor vehicles (26%) were the major contributors of PM10 in the Klang Valley (JICA, 1993).

As explained earlier, both PM10 and NO_2 can affect visibility. NO and CO have not been reported in literature as capable of absorbing or scattering light. However, their significant correlations with visibility can be explained by their association with motor vehicle sources, and thus their co-correlations with PM10 and NO_2.

During the period from August 1 to September 4, there was no reported source of air pollution outside Peninsular Malaysia such as forest fire or volcanic eruption. This means that most of the measured pollutants would most probably be from local sources, and motor vehicles seem to be the most significant contributor to visibility reduction during the study period. The role of motor vehicles as sources of visibility-reducing pollutants can also be explained by the insignificant correlation between visibility and SO_2. SO_2 will form sulfate particulates which have been implicated in haze formation (Husar & Wilson 1993). As shown by Table 2, there is some correlation between visibility and SO_2 but it is statistically insignificant. One explanation for this is that as SO_2 is more related to coal and fuel oil combustion sources and not motor vehicles, its correlation to visibility is not strong because visibility reduction during this study period is more related to pollutants from motor vehicle sources.

An interesting finding of this study is the significant inverse correlation between visibility and rainfall, which means that rain results in visibility reduction. To a certain extent, this can be explained by the fact that water vapour also reduces light transmission. However, this effect should only last for a few hours after it rains, and therefore should not affect the mean 24-hour visibility data which were used in the correlation analysis. The other explanation is that the presence of water vapour in the atmosphere triggers gas-to-particle conversion processes, whereby NO_2 and SO_2 are converted first to nitric and sulfuric acid mists and then to nitrate and sulfate particulates, respectively. The particulates formed then result in reduced visibility through light scattering. Therefore, intermittent rain as occurred throughout this study period may be ineffective in improving visibility but may in fact worsen it.

The above findings support a similar observation by Sham (1985) in his study which also suggested that rainfall scavenging of particulates in the free atmosphere, especially in urban centres, may not be as effective as it is under laboratory conditions. The same study also suggest that the reduction of particulates by rainfall is least effective, namely particulates which are most responsible for visibility reduction.

The critical pollutant from the human health perspective seems to be PM10. The concentration of these respirable particulates exceeded the RMAQG for 24-hour PM10 of 150 $\mu g/m^3$ on September 3 and 4. The 35-day mean of 82.2 $\mu g/m^3$ also exceeded the RMAQG for annual PM10 of 50 $\mu g/m^3$. According to the United States ambient air quality criteria for particulate matter, a PM10 level of 90 $\mu g/m^3$ can lead to increased respiratory disease symptoms among exposed populations (Stern et al. 1984). This health effect is probably already showing an impact on a sub-population of the Klang Valley, as another study conducted around the same time period by Zailina et al. (1996) has shown a significant correlation between atmospheric PM10 concentrations and the frequency of attacks among asthmatic children.

CONCLUSION

Comparison with an earlier study by Sham (1979) indicate that visibility in the Klang Valley may be worsening over the years. This study tend to suggest that the air pollutants most likely associated with visibility reduction in the Klang Valley during the study period are PM10 and NO_2. This observation then further suggest that the major contributors of visibility reduction are most likely motor vehicles and other local sources such fuel-burning factories, as they represent major sources of PM10 and NO_2. Results of the JICA (1993) study support this assumption. This may explain why NO and CO are also significantly correlated with visibility because they are also mainly from motor vehicle sources, even though they theoretically do not cause visibility reduction. This study also suggest that the atmospheric PM10 level over Klang Valley may reach critical unhealthy levels at times. This conclusion is also supported by the finding of another study by Zailina et al. (1996).

This means that Malaysians must therefore come to terms with the fact that local pollution sources may be contributing more to our visibility reduction problem than what might be realised. It is without doubt that foreign pollutant sources will aggravate our visibility reduction and local air pollution problem. However, until we realise that local sources are just as or more important, we will never be rid of this problem. This is now becoming more obvious to the residents of Klang Valley as the haze has become a rather permanent feature over their sky since the 1994 haze episode.

ACKNOWLEDGEMENT

The authors wish to thank the Malaysian Meteorological Services for supplying the visibility and rainfall data from their Subang Airport Meteorological Station, and the Department of Environmental Sciences of Universiti Putra Malaysia for providing air pollutant data from their monitoring station which they jointly operate with the Department of Environment.

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