

Diurnal Variations and Frequency Distribution of Air Pollutants Concentration in Kuala Lumpur and its Outskirts — A Preliminary Analysis

RIKITA INOUE and AZMAN ZAINAL ABIDIN

*Department of Environmental Sciences,
Faculty of Science and Environmental Studies,
Universiti Pertanian Malaysia,
43400 Serdang, Selangor, Malaysia.*

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ABSTRAK

Tiga buah stesen pengawasan udara yang berterusan telah didirikan di Kuala Lumpur, Serdang dan Kajang. Satu analisis awal telah dilakukan terhadap perubahan harian dan taburan kekerapan kepekatan bahan-bahan pencemar, dengan menggunakan data-data yang diperolehi dari 10hb. April — 5hb. Mei, 1985. Perubahan harian bagi bahan-bahan pencemar primer menunjukkan dua puncak yang jelas di Kuala Lumpur. Walau bagaimanapun, keadaan sedemikian tidaklah begitu ketara di stesen-stesen yang lain. Sebaliknya, bahan-bahan pencemar sekunder menunjukkan perubahan harian yang 'normal' di kesemua stesen tersebut. Analisis taburan kekerapan juga telah dibuat untuk memberikan perbandingan yang lebih jelas lagi terhadap kepekatan bahan-bahan pencemar di tempat-tempat tersebut.

ABSTRACT

Three continuous air monitoring stations were each installed in Kuala Lumpur, Serdang and Kajang. A preliminary analysis on the diurnal variations and frequency distribution of the pollutants concentration was made, using data obtained from 10th. April — 5th. May 1985. The diurnal variations for the primary pollutants showed two distinct peaks in Kuala Lumpur. These peaks were, however, not clearly defined at the other sites. Secondary pollutants, on the other hand exhibited 'normal' diurnal variations at all the sites. A frequency distribution analysis was also carried out to give a clearer comparison of the pollutants concentration, among the sites.

INTRODUCTION

Malaysia's involvement in the field of air quality is fairly recent. Officially, its involvement began after the gazettal of the Clean Air Regulations in 1978.

Air quality monitoring work was first carried out by the then Division of Environment in 1977 but it consisted mainly of short surveys.

These surveys produced limited data on which little analysis could be done.

Subsequently, more air quality monitoring programs were conducted by the Division, although more often than not, these were directed at problematic areas (May, 1979). Related studies were also carried out, from time to time, by other interested bodies and individuals, notably Sham Sani (1982).

While it cannot be denied that the results obtained from all these various studies do give an indication of the quality of the air in our country, most of them, if not all, suffered from one serious shortcoming — the sampling was not conducted continuously. A continuous sampling system is essential if one is to obtain more reliable and accurate information about the air quality of an area.

It is with this understanding that this paper is presented. As the sampling techniques used are not only continuous, but also among the most reliable, it is hoped that the information obtained will give us a better insight on the air quality of Malaysia, in general and of Kuala Lumpur and its environs, in particular.

MATERIALS AND METHODS

Location of Sampling Sites

Three sites were chosen based on certain criteria. Kuala Lumpur was selected as it represents an ideal urban setting. Kajang, some 24 kilometres south-east of Kuala Lumpur, was chosen to provide input for comparison between the air quality inside Kuala Lumpur and that in its outskirts. It has been proposed that the input from UPM, located about 20 kilometres south of Kuala Lumpur, be used as 'background' data for comparison with the other sites, as the air there is deemed to be relatively 'clean' (*Figure 1*). Other factors which has to be taken into consider-

ation (and which were no less important) included security, accessibility to the personnel at all times, and availability of electricity.

Thus, in Kuala Lumpur, City Hall was chosen. The height of the sampling is about 12 metres from the ground. The reason for this is to ensure that the data obtained is representative of a wider area, instead of just a street (as the case will be if the instrument had been placed at ground-level).

In Kajang, the sampling site was located inside the compound of the District Police Station. The height of the sampling inlet was about 3 metres from the ground.

In UPM, the system was installed in a room in the Department of Environmental Sciences. The sampling inlet was about 8½ metres from the ground.

Methods of Measurement

Each of sites was installed with a continuous monitoring set-up known as the micro-computer system for Air Monitoring (MCSAM). The air pollutants measured by the system were nitric oxide, nitrogen dioxide, oxides of nitrogen, carbon monoxide (in Kuala Lumpur only), ozone, sulphur dioxide and suspended particulate matter. The whole system was controlled by a micro-computer which prints out the average hourly data on each parameter in a form of tabulation by a dot-impact matrix line printer. Multi-point dot printing electronic strip chart recorders are also equipped to record the instantaneous value of each parameter.

Atmospheric concentration of nitric oxide (NO) was measured by a technique called gas-phase chemiluminescence (Fontijn *et al.*, 1970). When NO is reacted with excess ozone, electromagnetic radiation with wavelengths between 0.6–3 µm was emitted, the intensity of which was proportional to the NO concentration. NO was measured first and then nitrogen dioxide (NO₂) was reduced to NO by the use of a low-temperature carbon converter; the total concen-

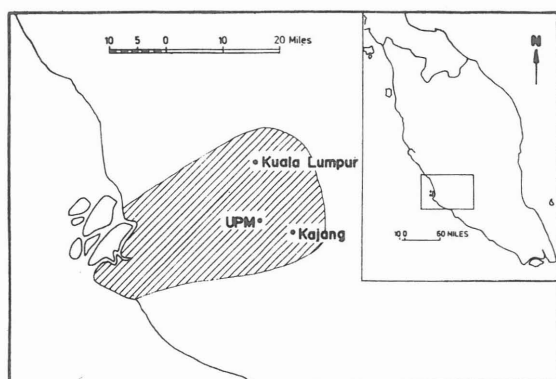


Fig. 1: Locations of Kuala Lumpur, UPM and Kajang in the Kelang Valley

tration i.e. the oxides of nitrogen (NO_x) ($= \text{NO} + \text{NO}_2$), was measured by drawing the sampled air through the reduction unit before entering a detector known as the photo-multiplier tube. The NO_2 concentration was obtained by the subtraction of NO from NO_x concentration.

The method used for sulphur dioxide (SO_2) measurements was based on the detection of the characteristic fluorescence released by the SO_2 molecules when they were irradiated by ultra-violet light (Okabe *et al.*, 1973). This fluorescence was also in the ultra-violet region of the spectrum, but at a different wavelength from the incident radiation. In this system, the exciting light source used was the Zn 213.8 nm. The fluorescence was detected by a photo-multiplier tube (PMT) after passing through a filter and the output of the PMT was further amplified by the use of an electronic amplifier which produced a voltage proportional to the fluorescent light intensity and SO_2 concentration.

The carbon monoxide (CO) concentration was measured by the non-dispersive infra-red (NDIR) method (Intersociety Committee, 1972). The method involved determining the difference in infra-red energy absorption between a gas sample containing carbon monoxide and a sealed reference sample consisting of an infra-red transparent gas. This difference in energy absorption, which was directly proportional to the concentration of the CO in the sample gas, was converted to an electrical signal (Kimoto Electric Co. Ltd., 1984).

Ozone (O_3) concentration was measured by the chemiluminescence method (Katz, M., 1976). The chemiluminescence resulting from the flameless gas-phase reaction of ethylene with ozone was detected by a photo-multiplier tube (PMT). The PMT converted the light intensity into electrical energy and amplified the energy; the output of the PMT was further amplified with an electronic amplifier (Kimoto Electric Co. Ltd., 1984).

The monitor used to measure the suspended particulate matter (SPM) concentration was similar to the conventional tape sampler, but

instead of visible light, beta-ray was used for the detection of the SPM concentration (Goulding *et al.*, 1978). The beta-ray flux emitted from ^{147}Pm was attenuated by passing through the filter tape. The transmitted flux was measured before and after sampling by means of a scintillation counter and associated electronics.

RESULTS AND DISCUSSION

Data obtained from 10 April to 5 May 1985 has been selected for the analysis.

Kuala Lumpur

Figure 2 shows the diurnal variations in the oxides of nitrogen, suspended particulate matter (SPM), carbon monoxide and sulphur dioxide concentrations (arithmetic mean) in Kuala Lumpur. An interesting feature observed here is the presence of two distinct peaks i.e. in the morning hours and late evenings. To give a clearer picture of the situation, the ratio between the average concentration of the pollutant for the hour and its total average concentration was obtained, and the results are shown in Figure 3. Except for SPM, the morning peaks of the pollutants are generally higher than their evening peaks. The morning peaks correspond to the morning traffic rush hours; hence there is a strong indication here that vehicular emissions

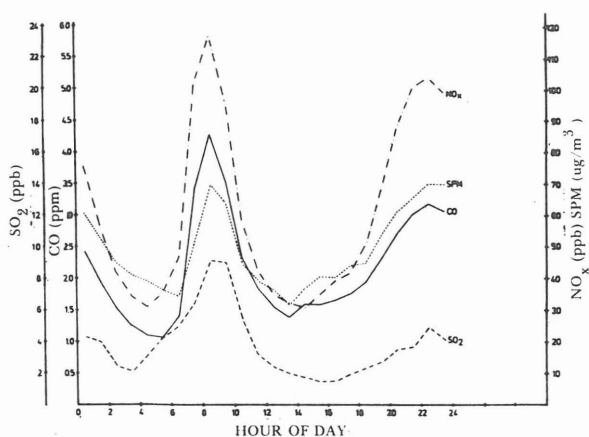


Fig. 2: Diurnal variations of oxides of nitrogen, SPM, carbon monoxide and sulphur dioxide concentrations in Kuala Lumpur. (10 April - 5 May 1985)

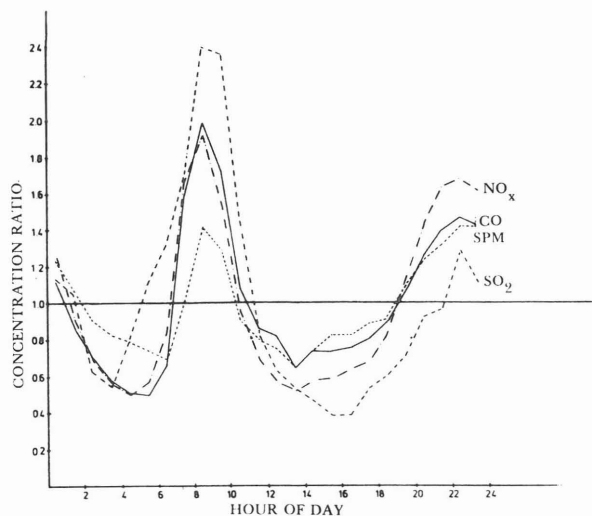


Fig. 3: Diurnal variations in oxides of nitrogen, SPM, Carbon monoxide and sulphur dioxide concentrations in Kuala Lumpur (10 April - 5 May 1985) (expressed as a ratio between average hourly concentration and total average concentration of the pollutant)

are the main contributory sources. As for the evening peaks, the authors are of the opinion that meteorological factors may play an important role here. It should be noted here that diurnal variation patterns which have two peaks are usually observed when emissions are from lower level sources than the sampling point (DeMarrais, 1977).

It is observed that, generally, the standard deviation from the hourly average pollutant concentrations are greater in the evenings than in the day-time, as the example in Figure 4 will show. It can be deduced that on some evenings, the concentrations of the pollutants can be rather high, while on others they can be quite low. One might tend to consider also that the standard deviation may be proportional to the hourly average concentration of the pollutant. However, as shown in Figure 5, the ratio of the standard deviation to the hourly average concentration is still seen to be greater in the evenings than in the day-time. Thus, it is more likely that the high concentration of the pollutants in the evenings be attributed to some meteorological factors, such as the occurrence of low mixing depths (coupled possibly with weak winds).

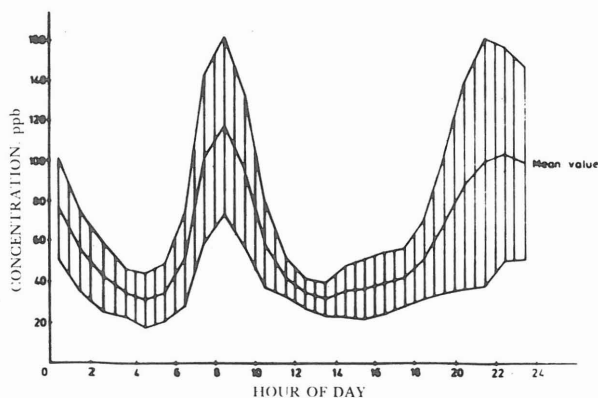


Fig. 4: Standard deviations of the diurnal average NO_x concentration in Kuala Lumpur (10 April - 5 May 1985)

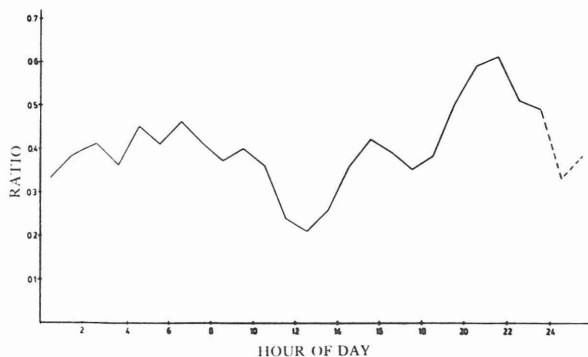


Fig. 5: Diurnal variations of Sx^x (The ratio of the standard deviation to the hourly average concentration) of oxides of nitrogen in Kuala Lumpur (10 April - 5 May 1985)

A comparison between the diurnal variations in nitric oxide, nitrogen dioxide, and ozone concentrations is shown in Figure 6. This observation is made to indicate the possibility of photochemical smog formation in the city. Two to three hours after dawn, the daily injection of nitric oxide (and hydrocarbons) from motor vehicles is well underway, and nitrogen dioxide begins to be generated at a fast rate. Usually within 1 to 2 hours, the nitric oxide is reduced to low concentrations because most of it has been converted to nitrogen dioxide. The decrease of nitric oxide in the late morning hours coincides with the appearance of ozone in the atmosphere. Ozone now accumulates until, sometime after noon when it reaches a maximum; it then

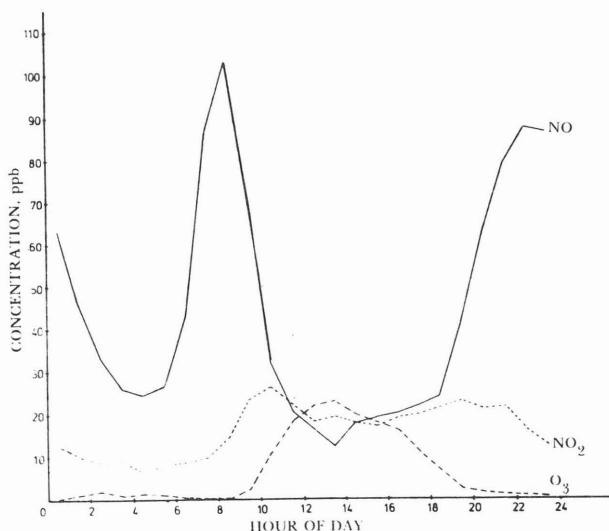


Fig. 6: Diurnal variations in nitric oxide, nitrogen dioxide and ozone concentrations in Kuala Lumpur (10 April - 5 May 1985)

gradually declines during the next several hours. The concentration of nitrogen dioxide usually declines from its peak as the ozone builds up. The after-office traffic injects an additional burden of nitric oxide into the atmosphere, which scavenges the remaining traces of ozone by early evening. Then the nitric oxide (and other primary pollutants) reaccumulate for the remainder of the night.

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The diurnal variations in oxides of nitrogen, SPM and sulphur dioxide concentrations, as shown in Figure 7, exhibit a similar pattern to that in Kuala Lumpur. Morning and

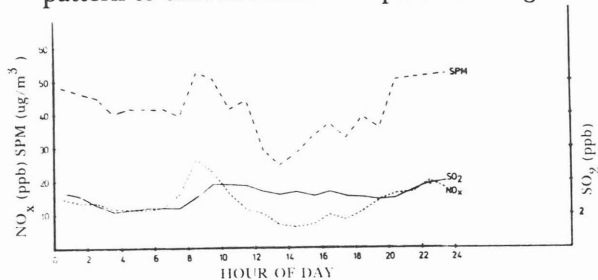


Fig. 7: Diurnal variations in oxides of nitrogen, SPM and sulphur dioxide concentrations in UPM, Serdang (10 April - 5 May 1985)

evening peaks are observed, although the concentration of NO_x is much lower than in Kuala Lumpur. Another feature observed is that the fluctuation in the diurnal variation in SO₂ concentration is much smaller than that in Kuala Lumpur, fluctuating just between 2 and 4 ppb.

Figure 8 shows the diurnal variations in NO, NO₂ and O₃ concentrations. As in Kuala Lumpur, the morning peak is first reached by NO, followed by NO₂ and finally by O₃ several hours later. A specific feature observed here is the relatively low NO concentration and high O₃ concentration as compared to that in Kuala Lumpur. This could partly be explained by the fact that the relatively high emission of NO in Kuala Lumpur prevents the build-up of O₃ to higher concentrations. Moreover, the photochemical reaction necessary in the formation of O₃ takes several hours; hence it is not unusual for the point of highest concentration of O₃ to appear at the outskirts of the city. However, as non-methane hydrocarbons which play an important role in the atmospheric photochemical reactions were not measured at the stations, further inference would be difficult to draw.

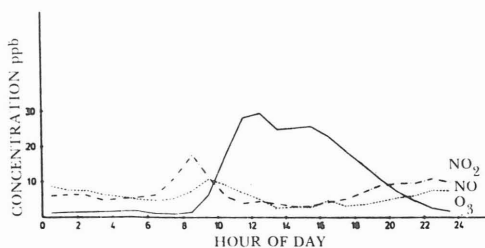


Fig. 8: Diurnal variations in nitric oxide, nitrogen dioxide and ozone concentrations in UPM, Serdang (10 April - 5 May 1985)

Kajang

A feature observed in Figure 9 is the earlier appearance of the evening peaks as compared to those in either Kuala Lumpur or UPM. As the sampling inlet is lower than at the other two stations, and also nearer to the main road, emissions from the motor vehicles would subsequently reach the sampling inlet earlier. As such, the

occurrence of the evening peaks, in this instance, would be more influenced by the emissions from motor vehicles passing through the road in front of the sampling inlet, and less by the local meteorology.

Another interesting observation here is the gradual increase of SO_2 from the early mornings towards the evenings. While not much can be said of this feature at this juncture, it is felt that local sources 'rich' in SO_2 may have brought about this particular occurrence.

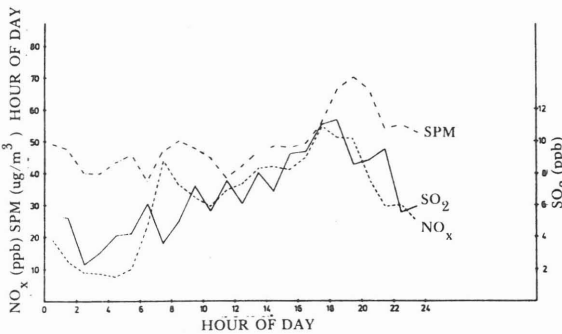


Fig. 9: Diurnal variations in oxides of nitrogen, SPM and sulphur dioxide concentrations in Kajang (10 April - 5th May 1985)

Figure 10 shows the diurnal variations in NO , NO_2 and O_3 concentrations. The maximum concentration of O_3 is almost that of UPM's and appears round about the same time as the other two stations. The NO and NO_2 concentrations are somewhat higher than in UPM, but is much lower than in Kuala Lumpur, especially so in the case of NO .

Although the diurnal patterns observed in Figures 2 and 7 can also be found in many sampling sites around the world, there are not, however, the 'standard' patterns as there are many others that show somewhat different variations. More in-depth analyses of the concentration variations, in relation to factors such as local meteorology, are needed to explain the occurrence of any one pattern.

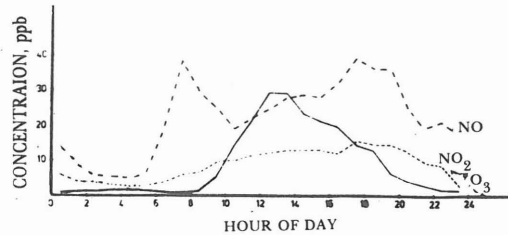


Fig. 10: Diurnal variations in nitric oxide, nitrogen and ozone concentrations in Kajang (10 April - 5 May 1985)

Frequency Distribution Analysis

Figures 11 to 14 show the cumulative frequency distribution of the pollutant concentrations at the 3 sites, plotted on the log-probability paper. From Figure 11, it is observed that the SPM concentrations in Kuala Lumpur and Kajang are rather close to each other, while that

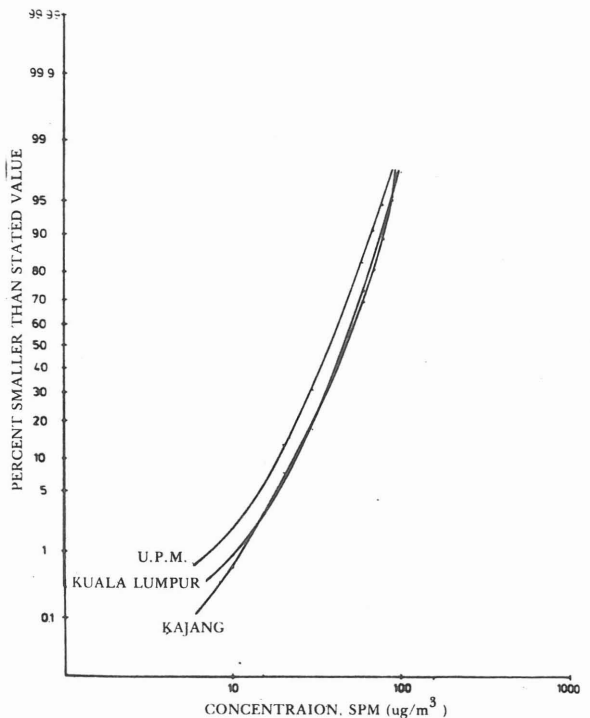


Fig. 11: Cumulative frequency distribution of the diurnal suspended particulate matter levels in Kuala Lumpur, Kajang and UPM (10 April - 5 May 1985)

of UPM is slightly less. However, the highest percentiles for all the sites come close to one another. An inference that can be made of this is that, statistically, the SPM concentrations outside the city is not that much lower than that inside the city itself, especially where incidence of high concentration periods is concerned. This statement, however, should be treated with caution, as the difference in height of the sampling inlets at the 3 sites may play a part in contributing to such a result.

The nitric oxide concentration is seen to be highest in Kuala Lumpur and lowest in UPM (Figure 12). This can be quite as expected as the chief source of nitric oxide at those sites is considered to be the motor vehicle, and there are generally more motor vehicles plying the roads of Kuala Lumpur than of either Kajang or UPM.

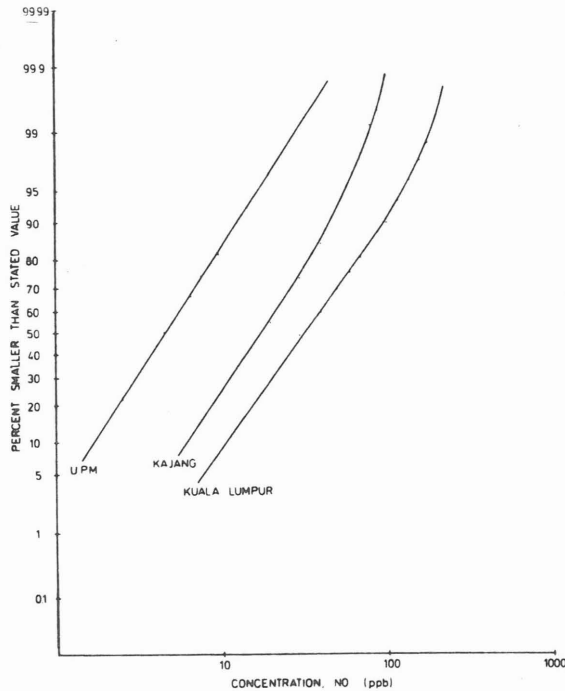


Fig. 12: Cumulative frequency distribution of the nitric oxide levels in Kuala Lumpur, Kajang and UPM (10 April - 5 May 1985)

Similarly, the nitrogen dioxide concentration in Kuala Lumpur is highest while that in UPM is lowest (Figure 13). The higher concentration of nitric oxide in Kuala Lumpur could mean that more of it is readily available for conversion to nitrogen dioxide, resulting in a higher nitrogen dioxide concentration.

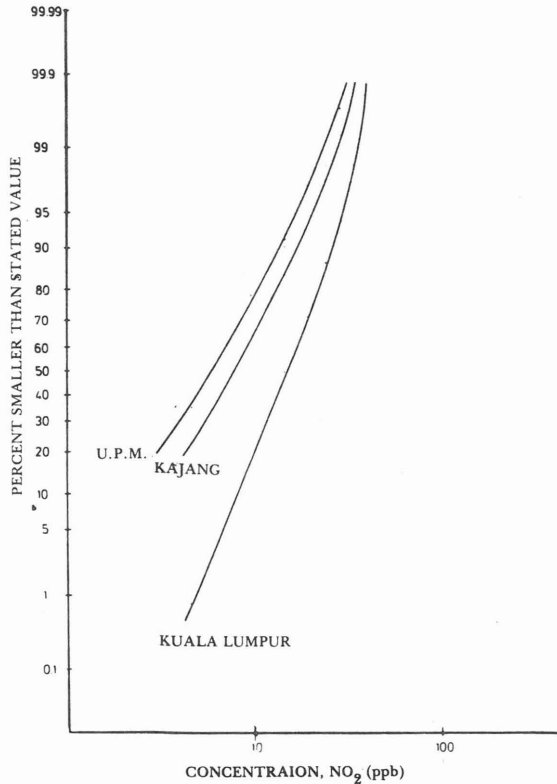


Fig. 13: Cumulative frequency distribution of the nitrogen dioxide levels in Kuala Lumpur, Kajang and UPM (10 April - 5 May 1985)

Figure 14 is somewhat interesting. The sulphur dioxide concentration in Kajang is the highest among the 3 sites. It must be noted here, however, that the sulphur dioxide concentrations at all the sites are rather low. Any emission source of sulphur dioxide, even if it is small, can give a distinct difference in the results obtained. Hence, in Kajang, local emission sources, relatively 'rich' in sulphur dioxide, could have accounted for the higher concentrations obtained.

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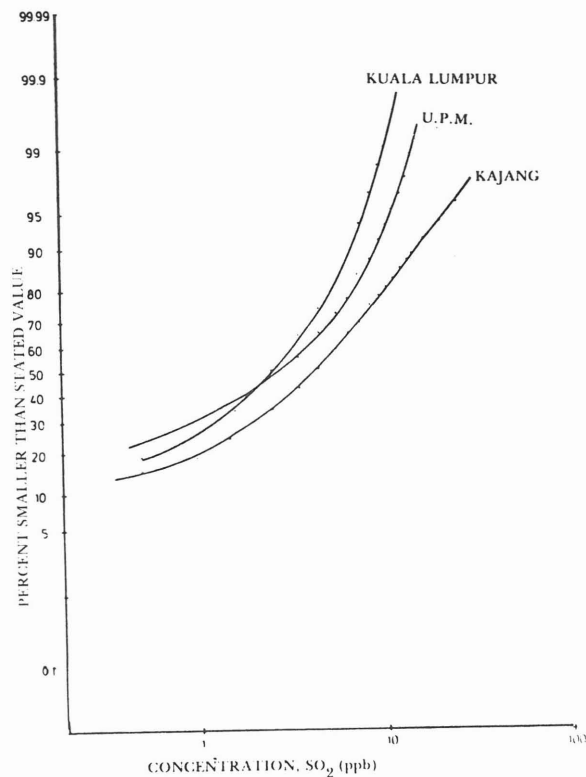


Fig. 14: Cumulative frequency distribution of the sulphur dioxide levels in Kuala Lumpur, Kajang and UPM (10 April - 5 May 1985)

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