Pertanika 9(2), 193 – 199 (1986)

# A Study of the Air Quality in Underground Car Parks with Emphasis on Carbon Monoxide and Airborne Lead

M.I. YAZIZ and A.W.P. YEN
*Department of Environmental Sciences,*
*Faculty of Science and Environmental Studies,*
*Universiti Pertanian Malaysia,*
*43400 Serdang, Selangor, Malaysia.*

**Key words: Air pollution; indoor air quality; carbon monoxide; lead.**

## ABSTRAK

*Paras karbon monoksida dan plumbum di dalam tiga buah tempat letak kereta tertutup di Kuala Lumpur telah dikaji bersama-sama dengan bilangan lalu-lintas selama tiga bulan. Semua bacaan di ambil pada ketinggian 1.5 m daripada bumi dalam jangka masa 8 – 13 jam. Hasil kajian menunjukkan variasi yang besar untuk paras plumbum iaitu daripada 1.75 hingga 33.0* $\mu g/m^3$ *bersamaan dengan perbezaan bilangan kenderaan. Purata bacaan karbon monoksida juga berbeza daripada 23.2 hingga 65.2 bsj di tempat-tempat kajian tersebut. Paras purata untuk kedua-dua bahan pencemar ini di ketiga-tiga tempat kajian telah didapati melebihi cadangan piawai kualiti udara Malaysia iaitu 0.7* $\mu g/m^3$ *untuk plumbum dan 9 bsj (purata 8 jam) untuk karbon monoksida. Suatu korelasi positif telah didapati untuk bilangan lalu-lintas dengan paras karbon monoksida dan juga plumbum.*

## ABSTRACT

*The concentrations of carbon monoxide and airborne lead in three enclosed underground car parks in Kuala Lumpur were measured simultaneously with traffic flow for a period of three months. The measurements were taken at a height of 1.5 m from the ground for a duration of 8 – 13 hours. A large variation in the airborne lead levels was observed which ranged from 1.75 to 23.9* $\mu g/m^3$ *in relation to traffic flow. The mean carbon monoxide concentration ranged from 23.2 to 65.2 ppm. The mean concentration of both pollutants at all the three sites was found to exceed the proposed Malaysian Air Quality Standard of 0.7* $\mu g/m^3$ *for lead and 9 ppm (8 hours average) for carbon monoxide. A positive correlation was observed between traffic flow and carbon monoxide as well as lead at the locations studied.*

## INTRODUCTION

It is becoming increasingly uneconomic to use valuable surface land as car parks in the big towns and cities. Thus the need of space for car parks in many new high rise establishments and complexes is often met by constructing deep basements or above ground multi-storey car parks. A factor of concern with regard to underground car parks is the health implications to users and personnel manning the car parks. This is because the motor vehicle exhaust emission contains a variety of potentially harmful, substances including carbon monoxide, oxides of nitrogen, sulphur dioxide, hydrocarbons, and fine particulates (including lead) which are discharged into the atmosphere. Under poor ventilation conditions, the level of these contaminants will rise posing hazards to human health.

The city of Kuala Lumpur has many underground car parks. They are located in hotels, shopping complexes, private residential buildings, and one has been planned for construction underneath a playfield (Anon., 1985). Although many studies have been carried out to determine the state of air pollution in the city, there has been only one study which examined the levels of carbon monoxide in some enclosed car parks (Anon., 1983). In view of the limited information available, this study was carried out to examine the air quality in several underground car parks in Kuala Lumpur with emphasis on carbon monoxide and particulate airborne lead.

## EXPERIMENTAL METHODS

### *Location of the Study*

Three enclosed underground car parks in Kuala Lumpur were chosen for the study. They were the basement car parks in an office building (underground car park (UCP 1), and in two shopping complexes (UCP 2 and UCP 3). All are located in similar environmental settings along busy streets in commercial areas of the city.

The sampling site in each underground car park was determined from the results of a preliminary survey in order to select a representative area which was as far away as possible from the nearest car and ventilation points. Sampling was carried out over a period of 3 months from Sept. → Dec. 1984.

### *Measurement of Carbon Monoxide*

The carbon monoxide (CO) level was measured using a portable Carbon Monoxide Tester (Riken; Model EC-231 B) fitted with a chart recorder. It has a measuring range of 0 to 300 ppm CO with an accuracy of ± 5%. The air flow rate was fixed at 1 litre per minute and the CO readings were recorded continuously. Measurements were taken at a height of 1.5 m from the ground. The sampling period ranged from 8 to 13 hours during weekends depending on the UCP. The instrument was calibrated prior to every sampling using standard CO gas (25 ppm).

### *Measurement of Airborne Lead*

Lead containing particulates were collected on 0.45 $\mu$ glass fibre filters by drawing air through the filter at the rate of 1.5 – 1.7 $m^3$ per minute using a High Volume Sampler (HVS) (Model Sierra 352). The exact flow rate was plotted continuously on chart paper. The sampling period for lead was fixed at 8 hours. The lead concentration was measured after digestion in nitric acid using an Atomic Absorption Spectrophotometer.

### *Traffic Flow*

Traffic flow was recorded in terms of the number of vehicles entering or leaving the floor while sampling was being conducted. The total number of vehicles per 30 minute intervals was recorded.

### *Ambient Air Temperature*

The ambient air temperature was measured using an ordinary mercury thermometer calibrated at 0.5°C intervals.

### *Analysis of Data*

The CO concentrations was averaged for every 5 minutes recording and a 30 minute mean CO value was obtained by averaging the 5 minute values. The data was analysed using the Statistical Package for Social Sciences (SPSS) programme in the University's Computer Centre.

## RESULTS

### *Pollutant Concentrations*

The range of lead and carbon monoxide concentrations and the ambient air temperature in each of the car parks are shown in Table 1. The maximum level recorded for lead was 23.9 $\mu g/m^3$ and the minimum was 1.75 $\mu g/m^3$, for

TABLE 1
The range of pollutant levels detected in the underground car parks in the study

| Site | Lead ($\mu g/m^3$) | | CO (ppm) | | Temperature (°C) | |
|---|---|---|---|---|---|---|
| | Range | Mean | Range | Mean | Range | Mean |
| UCP 1 | 1.7 – 11.0 | 6.1 | 6 – 85.0 | 23.2 | 29.0 – 33.0 | 30.4 |
| UCP 2 | 7.1 – 19.3 | 12.0 | 10 – 300.0 | 59.9 | 30.0 – 35.5 | 32.8 |
| UCP 3 | 8.9 – 23.9 | 15.9 | 7 – 132.0 | 65.2 | 30.0 – 36.0 | 33.2 |

carbon monoxide 300 ppm and 6 ppm, and for the air temperature, 36°C and 29°C respectively.

Differences in the frequency distribution of 30-minute average carbon monoxide concentrations were observed for all car parks *(Figure 1 – Figure 3)*. At UCP 1 the CO distribution exhibited a log-normal distribution pattern. Relatively low readings were dominant with a median value of 45.5 ppm. Wide fluctuations were recorded at UCP 2 and UCP 3. The CO distribution at UCP 3 approximates to a normal distribution pattern and the median CO values for UCP 2 and UCP 3 were higher than for UCP 1 at 155 ppm and 69.5 ppm respectively. For all the sites, more than 90% of the measurements demonstrated carbon monoxide levels exceeding 10 ppm.

*Correlation Analysis*

*Carbon Monoxide and Traffic Flow.* The relationship between traffic flow and the level of carbon monoxide in each underground car park is shown in Table 2. The mean traffic flow was lowest for UCP 1 and highest for UCP 3. Correspondingly, the mean carbon monoxide concentration was highest for UCP 3 and lowest for UCP 1. Tests for the coefficient of correlation demonstrated poor correlation between traffic flow and carbon monoxide concentrations in UCP 1 (r = 0.26 at 99% confidence level) but was significant for UCP 2 and UCP 3.

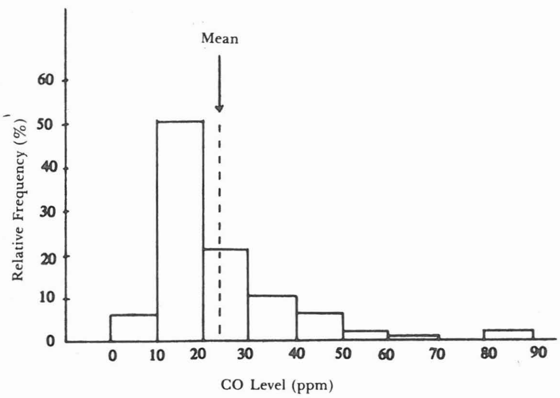


*Fig. 1: Frequency distribution of carbon monoxide levels at UCP 1*

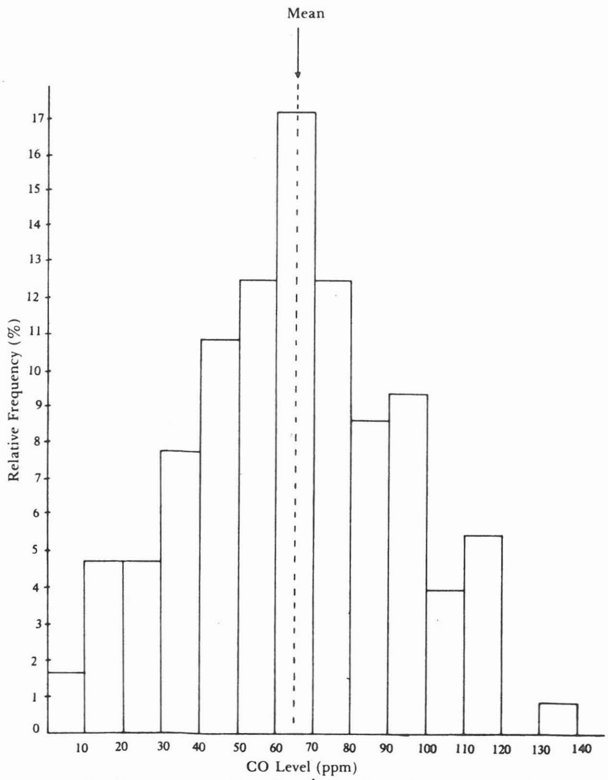


*Fig. 2: Frequency distribution of carbon monoxide levels at UCP 2*

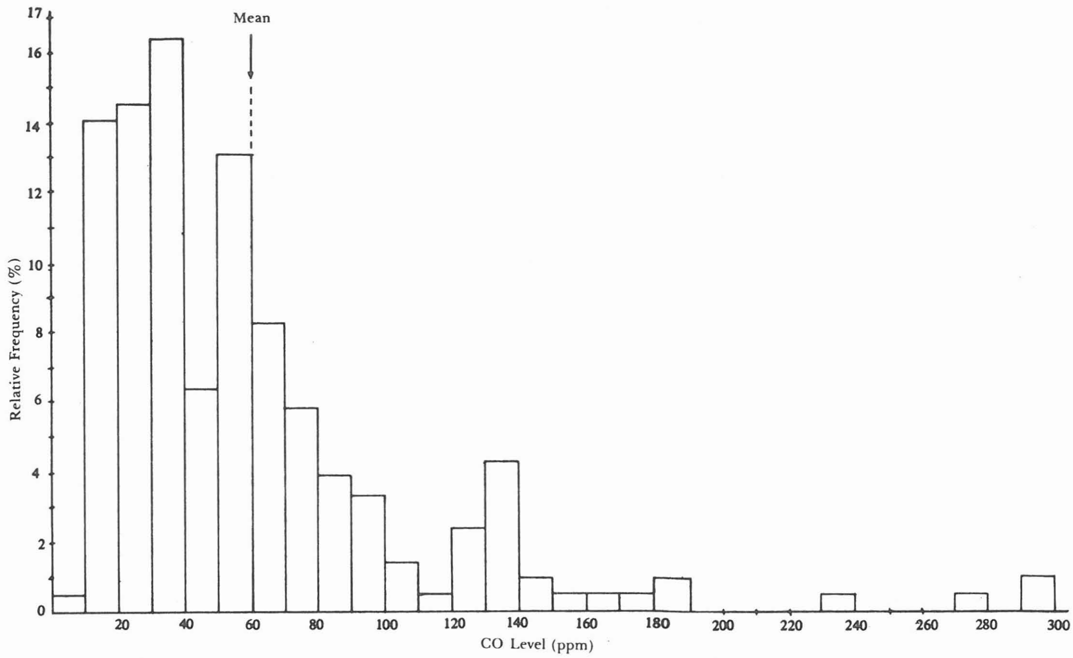


*Fig. 3: Frequency distribution of carbon monoxide levels at UCP 3*

TABLE 2
Relationship between CO concentration and traffic flow

| Site | Mean CO conc. (ppm) | Mean traffic Flow* | Corr. coef. | Level of significance |
|---|---|---|---|---|
| UCP 1 | 23.2 | 11 | 0.26 | 99.15 |
| UCP 2 | 59.9 | 32 | 0.69 | 99.99 |
| UCP 3 | 65.2 | 75 | 0.61 | 99.99 |

*Traffic flow: cars per 30 minutes.

*Airborne Lead and Traffic Flow.* A positive correlation between the airborne lead level and traffic flow was observed in UCP 2 and UCP 3 but not in UCP 1 (Table 3). The higher correlation in UCP 3 (r = 0.77) may be due to the fact that many vehicles pass through this floor at relatively fast speeds to and from the lower levels in this underground car park. It is known that the ratio of Pb/CO emission is highly dependent upon the driving mode of the car (Colucci *et al.*, 1968). High speed causes high emissions of lead but low carbon monoxide, and vice versa. Comparison of the data in Tables 2 and 3 show better correlation values between lead and traffic flow than carbon monoxide and traffic flow. These differences may be attributable to the different rates of sink processes for carbon monoxide and lead in the atmosphere.

Further analysis of the data showed changes in the correlation coefficient values between the air temperature and traffic flow (r = 0.04 at UCP 1, r = 0.63 at UCP 2, and r = 0.41 at UCP 3) and the air temperature and the level of carbon monoxide (r = 0.35 at UCP 1, r = 0.55 at UCP 2, and r = 0.67 at UCP 3) in the different car parks. Although the air temperature is expected to increase in line with the traffic flow,

TABLE 3
Relationship between airborne lead levels and traffic flow

| Site | Mean Pb level ( $\mu g/m^3$) | Mean traffic flow* | Corr. coef. | Level of significance |
|---|---|---|---|---|
| UCP 1 | 6.14 | 186 | 0.27 | 34.49 |
| UCP 2 | 12.09 | 690 | 0.68 | 95.66 |
| UCP 3 | 15.91 | 1316 | 0.77 | 92.34 |

*Traffic flow in cars per 8 hours.

the situation is somewhat complicated by changes in meterological factors outside the car parks. The effect of the heat from the car engine and exhaust emission on the air temperature inside the car park is very much influenced by the air supply from outside. On two occassions, a heavy downpour in the afternoon at UCP 3 caused a 2 degree Celsius fall in the air temperature in the car park within 30 minutes.

Carbon monoxide levels are also dependent on the air temperature but only as a secondary effect. Traffic flow is the dominant factor. A reduction in traffic flow might be expected to reduce the carbon monoxide level but a reduction in temperature may not. During hot weather, when the outside air temperature is high, the air temperature in the underground car park will increase in line with the increase in traffic flow together with the carbon monoxide level.

*Temporal Variation of Carbon Monoxide and Airborne Lead*

Typical temporal variations of the level of carbon monoxide and traffic flow in the different car parks are shown in *Figures 4* and *5*. The nature of use of the different buildings gives rise to different temporal variations of traffic flow and hence pollutant levels. In UCP 1, the peak traffic flows, although not very distinct, occurred just before 0800 hr, during 1300 to 1500 hr and at 1700 hr. Therefore the carbon monoxide levels were higher during these times. Both UCP 2 and UCP 3 are located in shopping complexes cum office buildings. Therefore the average traffic flow was much higher than in

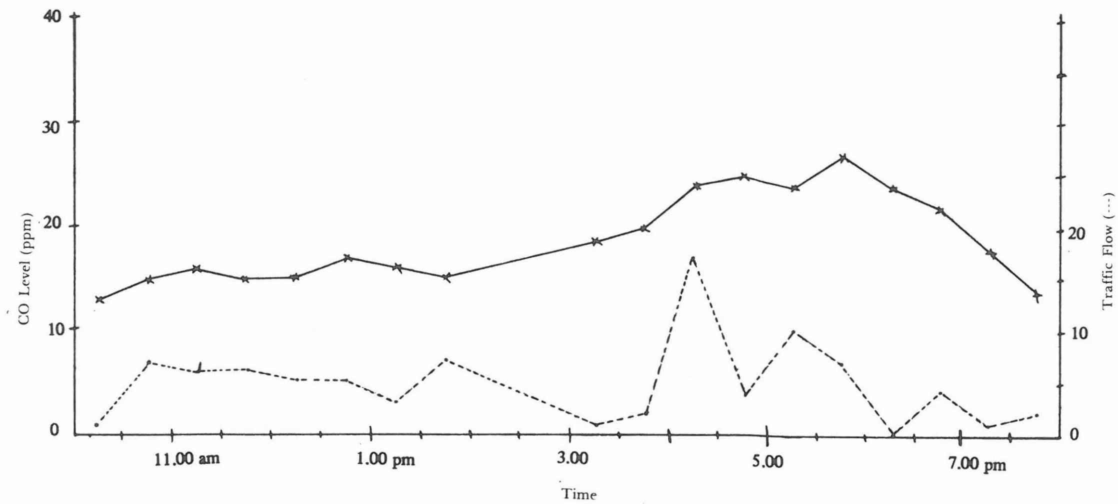


*Fig. 4: Temporal variation of carbon monoxide and traffic flow at UCP 1*

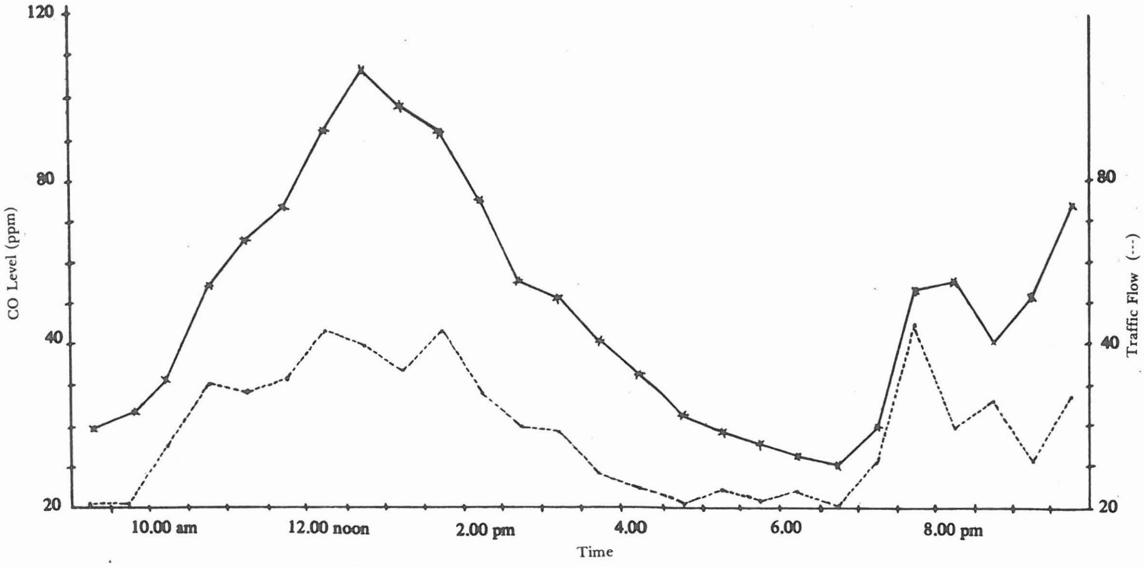


*Fig. 5: Temporal variation of carbon monoxide and traffic flow at UCP 2*

UCP 1. Hence the traffic flow was always on the high side compared to UCP 1. Measurements of the background carbon monoxide level in these UCPs (i.e. before any vehicle has entered in the morning) revealed that the CO values were either close to or exceeded the proposed Malaysian Air Quality Standard of 9 ppm (UCP 1 = 8 ppm, UCP 2 = 19 ppm, and UCP 3 = 10 ppm).

## DISCUSSION

More than 90% of the carbon monoxide concentrations measured exceeded 10 ppm in all the underground car parks studied. The mean CO concentration in all the UCPs also exceeded the proposed Malaysian Air Quality Standard of 9 ppm for an 8 hour average, and 35 ppm 1 hour maximum value (except in UCP 1). The occurrence of intermittently high levels of carbon monoxide exceeding 100 ppm in UCP 2 and UCP 3 is of concern with respect to its implication for human health. From the relationship between carboxyhaemoglobin in the blood and the carbon monoxide concentration in the air (Anon., 1959), light to moderate symptoms of carbon monoxide poisoning will be evident after 1 to 2 hours exposure in these car parks. The relatively lower CO values in UCP 1 can be accounted for by the smaller traffic volume since the building is primarily used as an office complex.

Lead is considered hazardous to human health due to its cumulative effect in the body. A comparison of all the sites revealed that UCP 3 has the greatest range of airborne lead. The maximum value recorded (23.9 $\mu g/m^3$) is very much higher than the value in the proposed Malaysian Air Quality Standard of 0.7 $\mu g/m^3$ for all zones. The average individual breathes in about 20 $m^3$ of air per day, which is equivalent to 0.14 $m^3$ per 10 minutes (Waldbott, 1978). Based on the mean lead level of 16 $\mu g/m^3$ (in UCP 3), a car park user or tenant who spends about 10 minutes in the car park each day would have inhaled 1.2 $\mu g$ of lead per day. Assuming that he uses the car park for 250 days in a year, he would have taken in 300 $\mu g$ lead per year. The amount retained in the alveoli is about 10% (Anon., 1972) i.e. about 30 $\mu g$ lead per year. Hence it would not take long for the lead concentration to accumulate to around 80 $\mu g$ lead per 100 gm blood which could well manifest in clinical symptoms of lead poisoning.

The high readings of carbon monoxide and airborne lead in all the underground car parks studied pose a potentially serious threat to the health of car park users or tenants. Especially at risk are the security personnel and car park attendants who patrol and manage the car parks daily. To reduce these problems, the traffic flow into the car parks should be strictly controlled to avoid overcrowding which would eventually produce excessively high levels of pollutants. In addition, knowledge of the daily peak traffic flow should be made available to the operating personnel so that they can switch on additional ventilation fans during peak hours.

The higher correlation of airborne lead concentration with traffic flow compared to carbon monoxide indicates that this approach to determining the air quality in enclosed car parks is more promising than using carbon monoxide as the reference. Since carbon monoxide is lighter than air, it tends to ascend and escape detection by the CO tester unless this is carefully sited. On the other hand, airborne lead, being more dense, is confined to the car park. This approach should be pursued until the lead content in petrol has been reduced to very low levels. Officially, the level of lead in petrol was reduced from 0.8 g/l to 0.4 g/l in April 1985 and it is anticipated that the government will initiate further reductions in the future.


## ACKNOWLEDGEMENTS

The expert advice and valuable assistance of Mr. Abu Bakar Che Man from the Factory and Machinery Department is gratefully acknowledged.


### REFERENCES


ANON., (1959): Ventilation of vehicular tunnels. The Institute for Highway Construction of the Swiss Institute of Technology. Report of the Committee on Tunnel Ventilation to the Swiss Department of Highways. *Bulletin* No. 10.

ANON., (1972): Health Hazards of the Human Environment. W.H.O. Publication. Geneva.

ANON., (1983): Carbon Monoxide Measurements At Covered Car Parks and in Residential Areas. Unpublished report by the Department of the Environment, Malaysia.

ANON., (1985): Underground Car Park for Selangor Padang. New Straits Times Press. 15 March 1985. Malaysia.

COLUCCI, J.M., BEGEMAN, C.R. and KUMLER, K. (1968): Analysis of Exhaust Emissions. Sixty-first Annual Meeting, Air Pollution Control Association. St. Paul, Minn. June 1968.

WALDBOTT, G.L. Ed. (1978): Health Effects of Environmental Pollutants. The C.V. Mosby Company, Missouri, U.S.A.


*(Received 19 October, 1985)*