World Applied Sciences Journal 8 (8): 1013-1021, 2010
ISSN 1818-4952

Concentration of Air Pollutants During Working and Non-Working Days in the Kuala Lumpur City Centre, Malaysia

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Abstract: This study was carried out to determine the air quality in the residential and industrial areas of Kuala Lumpur city centre, based on the concentrations of sulphur dioxide (SO_2), carbon monoxide (CO) and nitrogen dioxide (NO_2) gases. Samplings were carried out for a total period of four days per week comprising two working and two non-working days for each station from July 2006 until October 2006. Vulnerable analysis (VA) was carried out to evaluate the air pollution stress at the different locations. The Vulnerability Index (VI) values showed that the air quality in these stations was medium to high medium. Values of the average concentrations of SO_2, CO and NO_2 were 0.077±0.028, 11.742±1.917 and 0.094±0.027 ppm respectively. The results also showed that the concentrations of the pollutants were below the respective maximum permissible values stipulated by the Malaysian Department of Environment (DOE) (SO_2 = 0.13 ppm; CO = 30 ppm; NO_2 = 0.17 ppm). Statistical analysis showed that there was no significant difference ($p<0.05$) of the pollutant levels for working and non-working days. However, there was good correlation for the concentration of CO with the number of vehicles ($r=0.428$, $p<0.05$) passing through the sampling stations.

Key words: Kuala Lumpur City Centre Area · Sulphur dioxide (SO_2) · Carbon monoxide (CO) · Nitrogen dioxide (NO_2) · Vulnerability Index (VI)

INTRODUCTION

Polluted air causes a number of economic and social problems such as adverse effects on public health and environmental quality. Monitoring of data and studies on ambient air quality show that some of the air pollutants in several large cities are increasing with time and are not always at the acceptable levels as stipulated by the national ambient air quality standards [1]. The three major sources of air pollution in Malaysia arise from mobile, stationary and open burning activities. Emissions from mobile sources (i.e., motor vehicles) have been the major cause of air pollution, contributing to at least (70-75%) of the total air pollution. Emissions from stationary sources generally have contributed to 20-25% of the air pollution, while open burning and forest fires have contributed approximately to 3-5%. According to the Department of the Environment [2], Malaysia, the percentages of the air emission loads by type were motor vehicles (82%), power stations (9%), industrial fuel burning (5%), industrial production processes (3%), domestic and commercial furnaces (0.2%) and open burning at solid waste disposal sites (0.8%).

Transportation sources make up a significant portion of the four air pollutants: CO, NO_2, SO_2 and PM. At and near to the emissions sites, the concentration of certain pollutants may be so high that the health and well-being of humans and other living organisms are threatened, besides the serious impact it could have on constructed materials. Pollutants related to health problems in cities include NO_2, atmospheric aerosols ($PM_{2.5}$ and PM_{10}) and O_3 [3]. Air pollution is location-specific. It is greatest where it affects a larger number of people and the emissions result in high ambient concentrations. In the urban areas of Malaysia, air pollution is mainly caused by transportation sources, which cause pollution of the air through combustion processes and fuel evaporation. Transportation sources refer to a wide variety of vehicles that move, or can move from place to place. On road (or highway) sources include vehicles used on roads for transportation of passengers or freight (e.g., cars, trucks and buses). In Malaysia mobile sources include motor

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vehicles such as personal cars, commercial vehicles and motorcycles. By the end of the year 2000, there were 10.6 million vehicles registered in Malaysia, compared to 7.7 million in 1996, an increase of almost 2.9 million vehicles or 26% [4] in four years.

Air pollution from non-mobile sources is controlled under the Environmental Quality Act 1974, Environmental Quality Act 1999 [5-9] which is the main instrument used to achieve the objective of protecting the environment at the national level.

The air pollution in Kuala Lumpur city centre needs to be monitored regularly. The number of motor vehicles on the road are considerably higher especially during working days. The Kuala Lumpur city centre consists of not only shopping complexes, but offices as well as industrial and residential areas. Therefore, data on air pollution levels in the city centre is important to ensure that the levels do not exceed the acceptable limits.

The purpose of this study was to determine the concentrations of CO, NO_2, SO_2 in the air and the vulnerability index during working and non-working days in some selected areas in Kuala Lumpur.

MATERIALS AND METHODS

Air Pollutants Study: The study area comprised mixed industrial and residential areas of Kuala Lumpur City Center (Table 1). The samplings were carried out from July to October 2006.

The three parameters studied are carbon monoxide (CO), sulphur dioxide (SO_2) and nitrogen dioxide (NO_2). Sampling of the gaseous air pollutants was conducted by the method proposed by LaMotte [10]. Air was aspirated into a specific absorbing solution using an air pump at the flow rate of 1.0 L/min for SO_2 and CO gases, while for the NO_2 gas, air was aspirated into the specific absorbent solution at the rate of 0.2 L/min. The absorbent solution containing the gaseous sample was then treated with specific compounds to determine its concentration in the air. Readings were taken *in-situ* using the Spectrophotometer Hach Kit DR 2010. Transmission readings obtained were compared to the standard chart provided by LaMotte Chemicals [10] in order to obtain the actual concentrations in the air (in ppm). Samples were taken for one hour at the respective times: 0800-0900 hours, 1200-1300 hours, 1600-1700 hours and 2000-2100 hours, with an interval time of three hours between the four sampling times per day.

For comparison of the concentrations of CO, SO_2 and NO_2 between working days and non working days, the values were based on secondary data obtained from DOE-ASMA: CAQM stations covering July to October 2006, for other cities, i.e. Pasir Gudang in Johor, located in south Peninsular Malaysia (C1, coordinates: N 01° 28' 13.5", E 103° 53' 38.2"), Petaling Jaya in Selangor (C2, the nearest city to Kuala Lumpur; coordinates: N 03° 06' 36.7", E 101° 42' 16.4"), Kelang in Selangor (C3, coordinates: N 03° 00' 37.2", E 101° 24' 29.0") and Seberang Prai in Pulau Pinang, located in north Peninsular Malaysia (C4, coordinates: N 05° 23' 53.4", E 100° 24' 11.6").

Vulnerability Index Study: The vulnerability index is used to measure and identify the area in which the environment (including human beings) is at some stage of stress due to pollution. The information developed from the VI provides the basis for setting priorites in the planning of abatement measures and for requesting the various polluters to set up a budget for research, pilot studies and management of the pollutants. A total vulnerability score (VST) can be obtained from the following expression.

Table 1: Location of the study areas

Location	Longitude	Latiude
1. Jalan Tun Razak /Jalan Ampang (S1)	03° 09´ 34.4" N	101° 43´ 12.5" E
2. Jalan Ampang/Jalan P. Ramlee (S2)	03° 09´ 33.0" N	101° 42´ 39.8" E
3. Jalan Ampang/Jalan Sultan Ismail (S3)	03° 09´ 23.8" N	101° 42´ 19.4" E
4. Jalan Sultan Ismail/Jalan R. Abdullah (S4)	03° 09´ 33.5" N	101° 42´ 06.6" E

Table 2: The ranges of Vulnerability Index

Total vulnerability score (VST)	Vulnerability index (VI)
> 4420	Very high
4420-3315	High medium
3315-2210	High
2210-1661	Medium high
1661-1113	Medium
1113-517	Low
< 517	Very low

$$VST = \sum_{i=1}^{n} Xi\ Ti$$

Where Xi is the concentration of ith air pollutant, Ti the toxicity weighing factors for ith air pollution and n the number of air pollutants.

The toxicity weighing factors in this analysis as stipulated by the World Bank [11] for the pollutants such as NO_2, SO_2 and CO were 4.5, 1.4 and 0.004 respectively. The Vulnerability index was calculated on the basis of VTr, the threshold concentration for residential and sensitive areas (Table 2).

RESULTS AND DISCUSSION

Air Pollutants Study: The average concentration of CO was 11.742±1.917 in all the sampling stations (Table 3). The average concentration of CO was highest at the Jalan Ampang and Jalan Sultan Ismail intersection (S3) during working days, followed by that at the Jalan Ampang and Jalan P. Ramlee intersection (S2), the Jalan Sultan Ismail and Jalan R. Abdullah intersection (S4) and finally at the Jalan Tun Razak and Jalan Ampang intersection (S1) with values of 13.500±1.669, 12.938±1.591, 12.625±2.402 and 11.688±2.267 ppm, respectively. Fig. 1 shows the daily concentration pattern of CO gas (ppm) in the atmosphere for the four sampling stations. All concentrations of CO observed were below the maximum permissible value as stipulated by the DOE under the Environmental Quality Act, 1974 and the Environmental Quality Regulations (Clean Air), 1978, which is 30 ppm for a one hour period.

From the study it was found that the concentration of CO during the day was higher than that during the night and this could be correlated to human activities. The minimum concentration of CO was 7.500 ppm and the maximum value 16.00 ppm. For station S4 higher concentrations were recorded compared to S1, S2 and S3, possibly due to its proximity of being adjacent to the main road where the number of vehicles passing through were higher compared to those at the other stations (Table 4). Statistical tests (ANOVA) showed very significant differences ($p<0.05$) in the concentrations of CO between working and non-working days at all the sampling stations.

By comparing the data obtained in the current study to that of other studies it could be seen that the study area had higher concentrations of CO. A study conducted by Mohd Talib [12] in the Ayer Keruh and Teluk Kalung industrial areas showed pollution levels of 3.115-3.391 ppm. Correlation tests showed significant positive correlation ($r=0.42$, $p>0.05$) between CO levels and the number of vehicles plying in the area (Table 5).

Table 3: The daily average concentrations and standard deviations of toxic gases at all the four stations in Kuala Lumpur City Center [Average values (n=12) of toxic gases (ppm) for four intermittent one hour samplings at all the sampling stations from 8.00 am to 9.00 pm]

		Parameter		
Station	Day Status	SO_2	NO_2	CO
S1	Non-Working	0.061± 0.014	0.064± 0.021	10.625±1.157
	Working	0.074± 0.012	0.086±0.025	11.688±2.267
S2	Non-Working	0.066±0.100	0.064±0.021	10.625±1.847
	Working	0.076±0.009	0.085±0.026	12.938±1.591
S3	Non-Working	0.078±0.012	0.090±0.048	11.250±1.535
	Working	0.101±0.032	0.120±0.023	13.500±1.669
S4	Non-Working	0.071±0.014	0.101±0.028	10.688±2.865
	Working	0.087±0.027	0.139±0.024	12.625±2.402
Average		0.077±0.028	0.094±0.027	11.742±1.917
MPG		0.13	0.17	30

Note: MPG - Malaysian Permissible Guidelines for one-hour sampling

Table 4: Average number of vehicles, wind speed, temperature and relative humidity recorded for working and non-working days at the four sampling stations for different periods

	Non-working days				Working days			
Time	S1	S2	S3	S4	S1	S2	S3	S4
0800-0900								
Number of cars	3940	7305	8225	8400	8225	8275	10750	6280
Number of heavy vehicles	275	295	325	325	395	275	400	505
Number of motorcycles	805	1145	1350	1280	945	1120	1575	1690
Wind speed	0.8	1.85	0.6	1.35	1.2	1.7	1	2.30
Temperature	28.5	30.5	31	29	31.5	29	29	29
Relative humidity	62.5	65	80	70	62.5	55	80	57.5

Table 4: Continued

1200-1300								
Number of cars	8100	9035	10200	11135	10625	10170	13390	13720
Number of heavy vehicles	360	395	545	590	460	355	470	585
Number of motorcycles	965	350	1740	1295	1600	1815	1225	2420
Wind speed	1.65	5.7	2.05	2	6.55	5.1	2.025	3.85
Temperature	35	39.5	38	40	38	37.5	39	39
Relative humidity	52.5	23.1	62.5	48	45	37.5	55	42.5
1600-1700								
Number of cars	6175	6995	8920	10925	8970	9170	11700	13185
Number of heavy vehicles	295	319	385	445	375	295	425	525
Number of motorcycles	1385	1400	1907	1327.5	1635	2000	1815	2390
Wind speed	1.4	5.55	2.6	4,1	5.1	3.1	2.275	3.1
Temperature	35.5	38.5	36	37.5	36	33.5	37.5	36
Relative humidity	41	45	60	55	47	52.5	52.5	42.5
2000-2100								
Number of cars	6790	7305	9700	9550	8175	10495	10200	10870
Number of heavy vehicles	175	217	300	35	305	230	375	385
Number of motorcycles	1285	1670	1155	2120	1840	2025	1570	1705
Wind speed	1.05	3.65	2	1.6	5.65	2.645	2.275	2.65
Temperature	31	32.5	33	33.5	30	31.5	33	31
Relative humidity	48.5	52.5	75	62.5	55.5	32.5	47.5	55

Table 5: CO concentrations and vehicles numbers in the four sampling stations in Kuala Lumpur

Stations	CO	Vehicles
S1	11.2	3212
S2	11.8	3448
S3	12.3	4046
S4	11.6	4450

Significant correlations ($p>0.05$) were also noted between CO levels and ambient air temperature, relative humidity and wind speed. Norela et al. [16] reported that there were no significant differences ($p>0.05$) in the pollutant levels (CO, SO_2, O_3 and NO_2) between working days and non-working days in the mixed industrial and residential areas of Nilai town in Negeri Sembilan, Malaysia.

By comparing the data of the current study with the CO data obtained from DOE-ASMA: CAQM stations from July to October 2006 (Fig. 3), higher levels of CO were observed during working days compared to the non-working days. However all the concentrations observed were below the maximum permissible value as stipulated by the DOE under the Environmental Quality Act, 1974 and the Environmental Quality Regulations (Clean Air), 1978, which is 30 ppm for a one hour period.

The average concentration of SO_2 was 0.077±0.028 ppm at all the sampling stations (Table 3). The concentration of SO_2 was highest at the Jalan Ampang and Jalan Sultan Ismail intersection (S3) during working days, followed by that at the Jalan Sultan Ismail and Jalan Raja Abdullah intersection (S4), the Jalan Ampang and Jalan P. Ramlee intersection (S2) and and finally at the Jalan Tun Razak and Jalan Ampang intersection (S1), with values of 0.101±0.032, 0.087±0.027, 0.076±0.009 and 0.074±0.012 ppm, respectively. Fig. 3 shows the concentration pattern of SO_2 gas (ppm) in the atmosphere for the four sampling stations. All concentrations observed were below the maximum permissible value as stipulated by the DOE under the Environmental Quality Act, 1974 and Environmental Quality Regulations (Clean Air), 1978, which is 0.13 ppm for a one hour period.

From the study it was found that the concentrations of SO_2 during the day were higher than those during the night, which could be correlated with human activities that were closely related to the traffic volume at the day and night time (Fig. 4). The minimum concentration value of SO_2 was 0.050 ppm and the maximum value was 0.150 ppm. Station S3 recorded higher concentration values compared to S1, S2 and S4, possibly because the number of vehicles passing through was higher compared to those at the other stations. Statistical test (ANOVA) showed very significant differences in the concentration of SO_2 ($p<0.05$) for working days and non-working days in all the sampling stations (Fig. 5). Comparison with other studies showed that the study area had higher concentrations of SO_2. A study conducted by Norela *et al.* [13] in the Balakong industrial area in Selangor showed SO_2 levels of 0.012-0.045 ppm. ANOVA tests showed significant correlations ($p>0.05$) between SO_2 levels and the number of vehicles passing through the area. There were also significant correlations ($p>0.05$) between SO_2 levels and the ambient air temperature, relative humidity and wind speed.

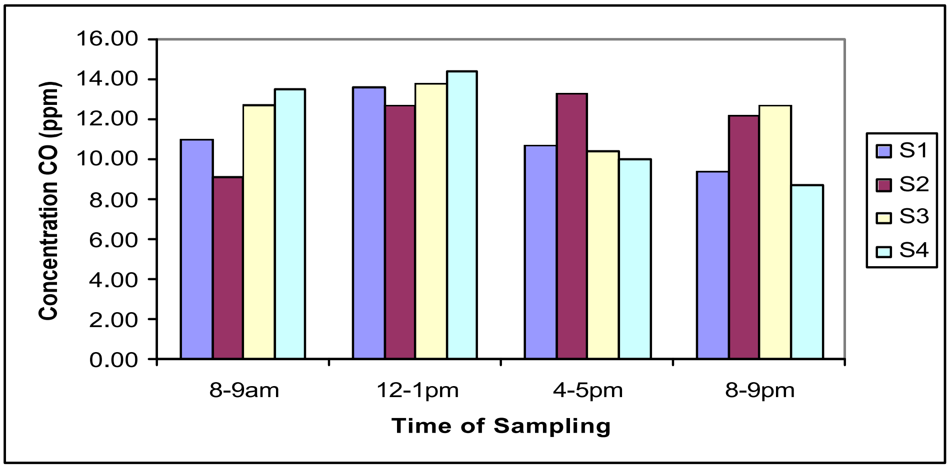


Fig. 1: The daily pattern of CO levels (ppm) at all sampling stations from 8.00 am to 9.00 pm

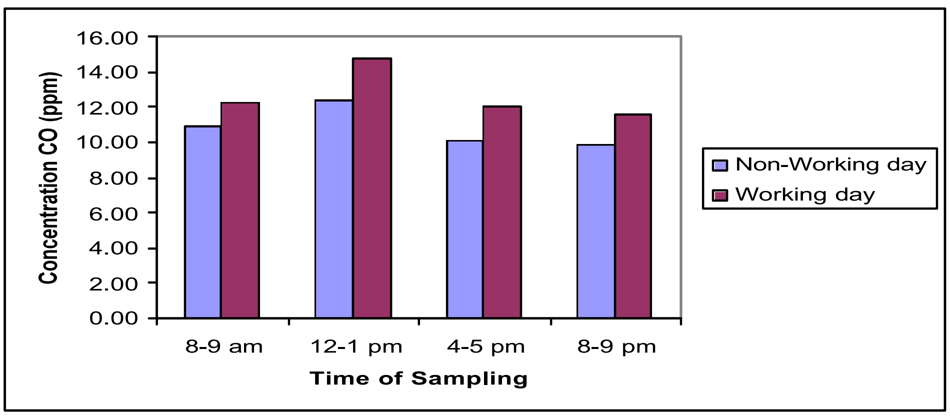
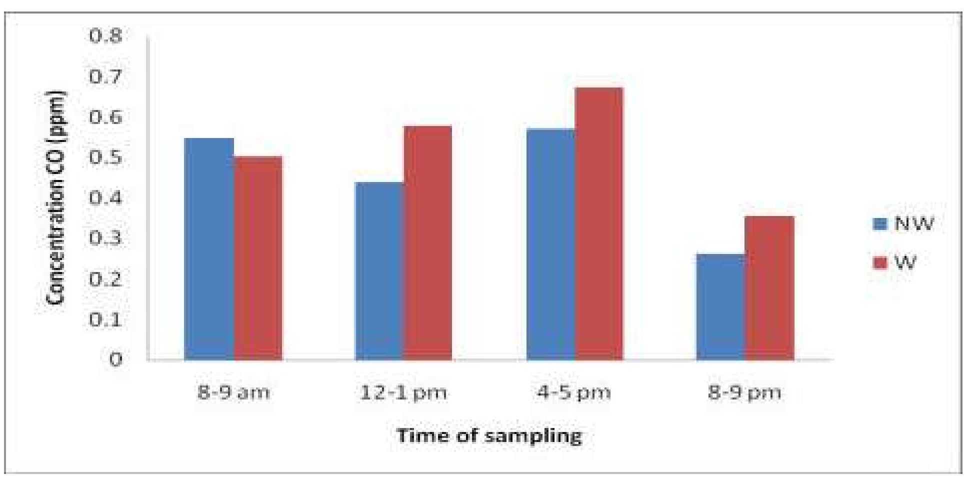


Fig. 2: Comparison of the concentrations of CO gas (ppm) pollution for working days and non-working days



Note: NW – non-working , W – working day

Fig. 3: Comparison of the levels of CO gas (ppm) pollution between working days and non-working days recorded as an average from other cities in Malaysia through the secondary data of DOE-ASMA: CAQM stations

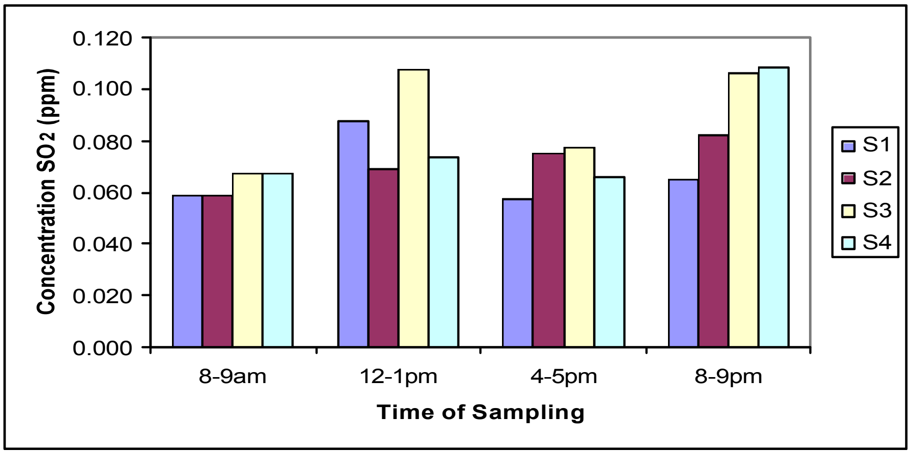


Fig. 4: Concentration patterns of SO_2 gas (ppm) at four sampling stations

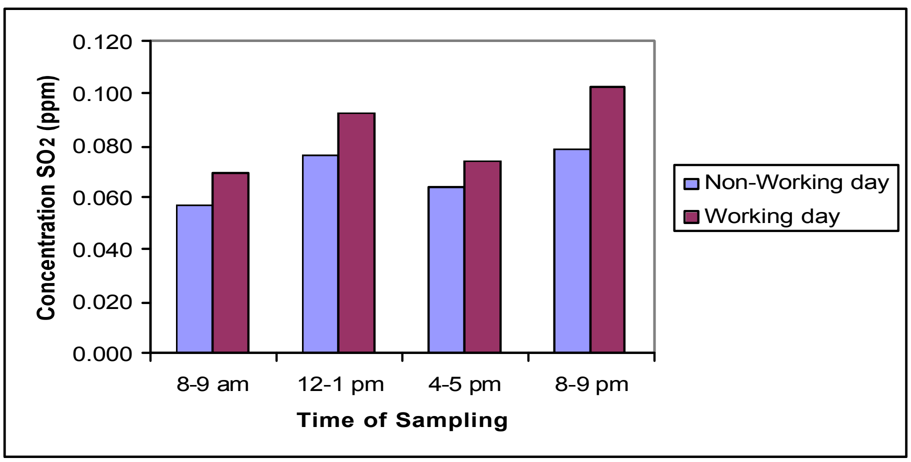
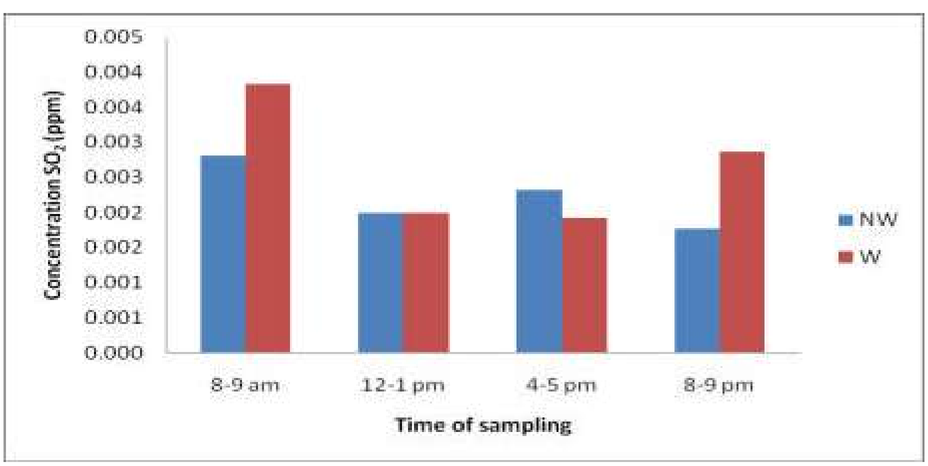


Fig. 5: Comparison of the concentration of SO_2 gas (ppm) for working days and non-working days at the four sampling stations



Note: NW – non-working , W – working day

Fig. 6: Comparison of the levels of SO_2 gas (ppm) pollution between working days and non-working days recorded as an average from other cities in Malaysia through the secondary data of DOE-ASMA: CAQM stations

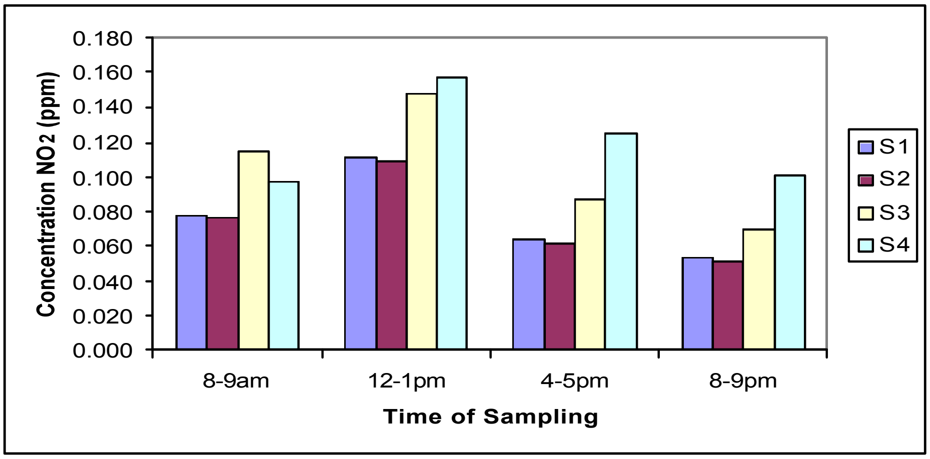


Fig. 7: Concentration patterns of NO_2 gas (ppm) at the four sampling stations in Kuala Lump ur

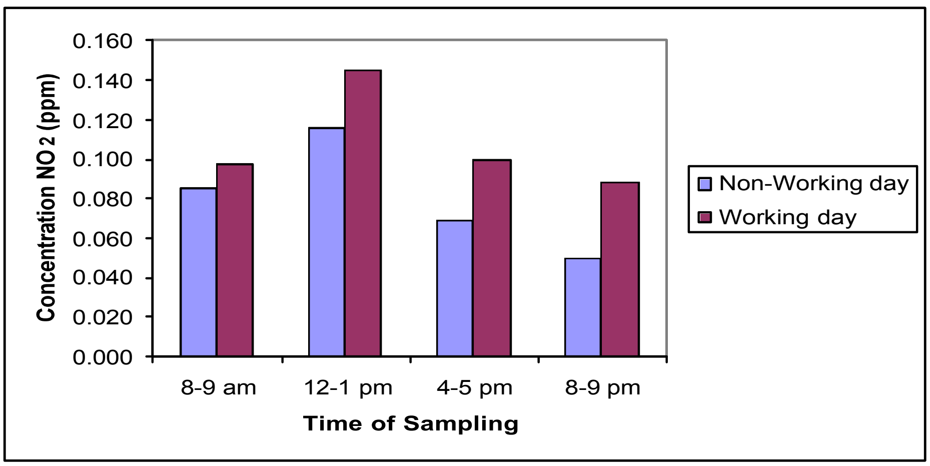
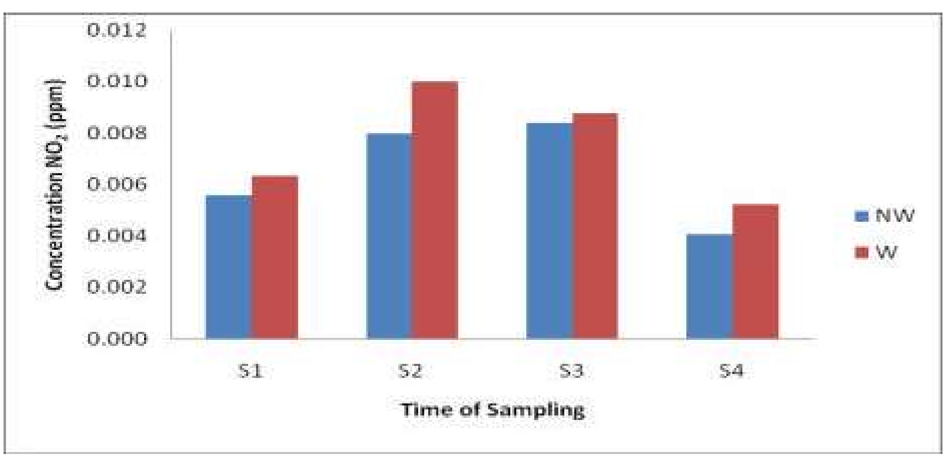


Fig. 8: Comparison in concentration of NO_2 gas (ppm) for non-working and working days at the four sampling stations in Kuala Lumpur city centre



Note: NW – non-working , W – working day

Fig. 9: Comparison of the levels of NO_2 gas (ppm) pollution between working days and non-working days recorded as an average from other cities in Malaysia through the secondary data of DOE-ASMA: CAQM stations

Table 6: Vulnerability analysis at the different sampling stations in Kuala Lumpur city centre

Station	Vulnerability scores (VS) SO_2	NO_2	CO	VST	VI
S1	252	630	511	1393	Medium
S2	266	630	540	1436	Medium
S3	336	900	567	1803	Medium high
S4	294	1035	534	1863	Medium high
Overall	287	799	538	1624	Medium

By comparing the data of the current study with the SO_2 data obtained from DOE-ASMA: CAQM stations from July to October 2006 (Fig. 6), it could be seen that levels of SO_2 during non-working days increased in the early morning and decreased during the afternoon, then increased again at night. However, all the SO_2 concentrations observed were below the maximum permissible value as stipulated by the DOE under the Environmental Quality Act, 1974 and Environmental Quality Regulations (Clean Air), 1978, which is 0.13 ppm for a one hour period. The same results were also reported by Norela *et al.* [16].

Average concentration of NO_2 recorded was 0.094±0.027 ppm at all the sampling stations (Table 3). The concentration of NO_2 was highest at the Jalan R. Abdullah intersection (S4) d uring working days, followed by that at Jalan Ampang and Jalan Sultan Ismail intersection (S3), the Jalan Tun Razak and Jalan Ampang intersection (S1) and finally at the Jalan Ampang and Jalan P. Ramlee intersection (S2) with values of 0.139±0.024, 0.120±0.023, 0.086±0.025 and 0.085±0.026 ppm, respectively.

Fig. 7 shows the concentration pattern of NO_2 gas (ppm) in the atmosphere at the four sampling stations. All concentrations observed were below the maximum permissible value as stipulated by the DOE under the Environmental Quality Act, 1974 and Environmental Quality Regulations (Clean air), 1978, which is 0.17 ppm for a one hour period.

The concentration pattern showed that NO_2 concentrations were higher in the morning and decreased towards the evening. The minimum value of NO_2 was 0.04 ppm and the maximum value 0.18 ppm. Station S4 recorded higher concentration compared to S1, S2 and S3. Statistical tests (ANOVA) showed very significant differences in the concentrations of NO_2 ($p<0.05$) for working and non-working days at all the sampling stations (Fig. 8).

NO_2 levels recorded in this study were higher than levels recorded in the Ayer Keruh and Teluk Kalung industrial areas [14] and those recorded along the Putrajaya road [15]. There was also a significant positive correlation ($r=0.62$, $p>0.05$) between NO_2 levels and the number of vehicles passing through the area. There was also significant correlation ($p>0.05$) between NO_2 levels and ambient air temperature, relative humidity and wind speed.

By comparing the data of the current study with the SO_2 data obtained from DOE-ASMA: CAQM stations from July to October 2006 (Fig. 9), higher levels of CO were observed during the working days compared to the non-working days. However, all concentrations observed were below the maximum permissible value as stipulated by the DOE under the Environmental Quality Act, 1974 and Environmental Quality Regulations (Clean Air), 1978, which is 0.17 ppm for a one hour period. The same results were also reported by Norela *et al.* [16].

Vulnerability Index Study: VA was carried out at road intersections taking into consideration the mean values of the pollutants and the results are given in Table 6. The VI is rated medium in two stations and for the other two it is high medium.

CONCLUSION

All three parameters of the pollutants studied were found to have values below the values permitted by the DOE under the Environmental Quality Act, 1974 and Environmental Quality Regulations (Clean Air), 1978. There were no significant differences ($p>0.05$) in the pollutant levels between working days and non-working days. The Vulnerability Index for overall stations is medium. The DOE and local authorities should cooperate and work closely regarding implementation of the laws as well as monitoring and managing the air and noise pollution problems. Settlement areas built close to industrial areas should have buffer zones so that air pollutants released from the industrial activities are not emitted directly to the surrounding residential areas.

ACKNOWLEDGEMENTS

We wish to acknowledge the technical assistance rendered by Mr. Azman bin Hashim and other technical staff from the Faculty of Science and Technology, Universiti Kebangsaan Malaysia and also those from the University of Malaya.

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