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Carbon Monoxide Monitoring at Stationary and Mobile Stations

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Abstract: This study was conducted to determine citizen exposures to CO in Kermanshah city. Measurements were made through 20 stationary and 54 mobile stations in different areas of the city and totally 2240 air samples were collected. Different variables such as weekly days, daytime (morning and afternoon), seasons, wind effects and taxi ages were investigated. The results showed that minimum CO concentration levels are existed at less traffic area stations in summer. But maximum levels of CO concentrations were observed in commercial area stations in winter and in all mobile stations CO concentration levels were very high. CO concentration variation levels were exceeded from 9 ppm for 8 h and 35 ppm for 1 h, as specified by US EPA at commercial area stations and all mobile stations. High concentration levels of CO concentrations belong to taxi cabin in fall season, so that by increasing taxi age (based on car making year or year of registration)) from 8 to 21 years, CO concentration levels came down and up in spring and summer, respectively. In addition, the results showed that CO concentration levels in even highly polluted of commercial area station decreases considerably on weekend (Friday) and at high wind speed of 3.5 m sec^{-1}. But, high CO concentrations levels were observed at different seasons in all mobile stations. Finally, variation patterns of CO concentrations inside of taxi cabin are related to the driving speed of taxi and CO peak concentrations after sudden brake are higher than 60 ppm.

Key words: Carbon monoxide, exposure, stationary station, mobile station, pollution

INTRODUCTION

Carbon monoxide (CO) is a colorless, odorless and tasteless gas. It is a byproduct of the incomplete burning of fuels. Industrial processes contribute to carbon monoxide pollution levels, but the principal source of carbon monoxide in most large urban areas is vehicle emissions (Flachsbart, 1999). From the late 1960s through the early 1980s, CO was a major air pollutant of concern. The adverse health effects associated with CO vary with its concentration and duration of exposure (WHO, 1999; Varon *et al*., 1999). CO concentrations of 10 to 100 ppm in ambient air and inside motor vehicles can exert adverse health effects on the general population(WHO, 1999; EPA, 1998; Aronow *et al*., 1974; Kurt *et al*., 1978; Godin *et al*., 1972). Because motor vehicle traffic is the major source of CO, daily concentration peaks coincide with morning and evening rush hours. The health threat from carbon monoxide is most serious for those who suffer from cardiovascular disease. CO emissions are substantially greater in cold weather because cars need more fuel to start at cold temperatures and some emission control devices such as oxygen sensors and catalytic converters operate less efficiently when they are cold (WHO, 1999; EPA, 1998). In many cities, in the USA high short-term peak CO concentrations (mean average of 50 ppm) occur in heavy traffic areas. In Tehran, Iran, more than 90% of carbon monoxide is produced by motor vehicles and CO concentration levels up to 120 ppm were found at west of this city. Exposure to these ambient CO levels may affect groups of people such as bus and truck drivers, police officers, vehicle inspectors, street repair workers, urban cleaners, street vendors, parking attendants, pedestrians and cyclists. Vehicle drivers are also exposed to CO from traffic and leakage of own vehicle's exhaust (WHO, 1999; EPA, 1998; Godin *et al*., 1972; Von Burg, 1999; Clifford *et al*., 1997). In urban traffic environments, the concentrations measured inside motor vehicles are generally higher than those measured in ambient air. The carbon monoxide levels are highest in personal cars, the mean concentrations being 2-5 times

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the levels measured in streets or inside subway trains (Rodolf, 1994; Dor *et al*., 1995; Fernsndez-Bremauntz and Ashmore, 1995). Traffic patterns, car model and maintenance, vehicle ventilation conditions and season are factors that affect the carbon monoxide levels inside the cars (Chan *et al*., 1991; Flachsbart, 1995; Zhang *et al*., 1995). US Environmental Protection Agency (EPA) had proposed 9 ppm for 8 h and 35 ppm for 1 h to protect susceptible population groups from adverse effects resulting from CO exposures in the outdoor environment (EPA, 1998). CO exposure continues to be a matter of great concern in the world due to its association with high incidence of morbidity and mortality. This study was conducted to determine citizen exposures to CO in some specified stationary and mobile stations in Kermanshah city, which is located at west part of Iran (450 km far away from Tehran) during 2003-2004. This city has 65 sq km areas and is located at 1322 m above sea level with a population of 800000. Mean average of rainfall is approximated 465 mm annual and mean air temperature varies from 14.2-9.2°C during spring and winter. Mean average of morning inversion at autumn and winter are 55 and 70%, respectively. Govern average wind velocity is approximately 4 m sec^{-1} in which 18% of that came from west and 16% from south east.

MATERIALS AND METHODS

This study was conducted to determine CO concentration in specified part of Kermanshah city, which is located at west part of Iran (450 km far away from Tehran) during 2003-2004. Carbon monoxide measurements have been conducted in 20 stationary and 54 mobile stations (inside taxi cabin). In both stations, 2240 samples (1120 samples in 20 stationary stations and the same for mobile station) were collected. Stationary stations have been selected based on polluted and estimated non-polluted areas in which they are included 5 at city center residential area, 5 at less traffic area (between 2-6 km away from city center), 5 at commercial areas (on the pavement), 3 and 2 stations at commercial-industrial and industrial areas, respectively. Air sampling monitoring has been measured by a CO direct-reading meter with a resolution of 0.1 ppm. All measurements were conducted seasonally (spring to winter) at the middle of each season for a full week in the morning (8-12 am) and afternoon (15-17 pm). Sampling time at stationary stations was 5 min and in taxi cabin based on the distance of stationary stations varies from 3-8 min. Cigarette smoking is prohibited for both taxi driver and passengers during sampling time.

RESULTS

Rapid examination of data shown in Table 1 indicates high levels of CO concentrations at commercial area stations. Also, Table 2 presents the annual values of CO concentrations at different stations during whole weekdays are higher than 8 h CO standard concentration.

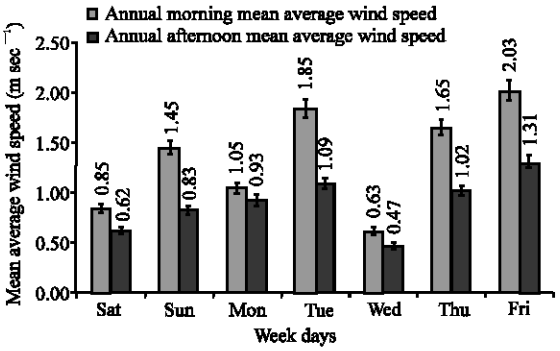

Fig. 1: Annual mean average of wind speeds in the morning and afternoon during week days

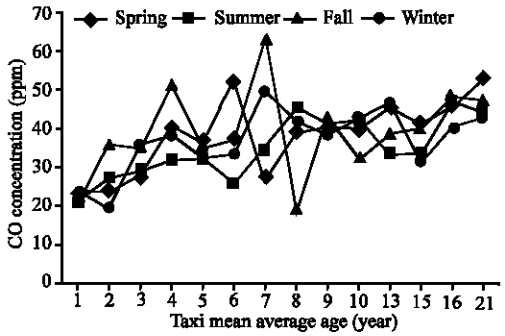

Fig. 2: Mean average CO concentration for different taxis age in various seasons

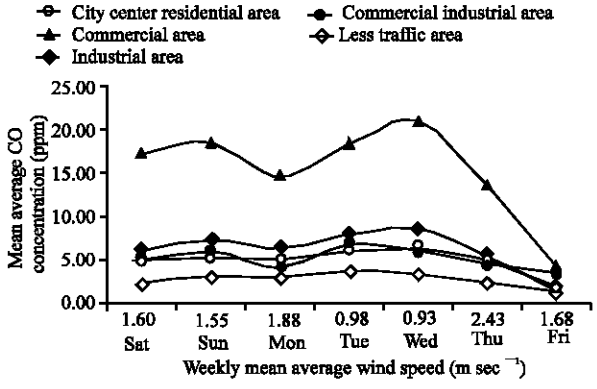

Fig. 3: Annual mean average of CO concentrations during weekdays at different wind speeds

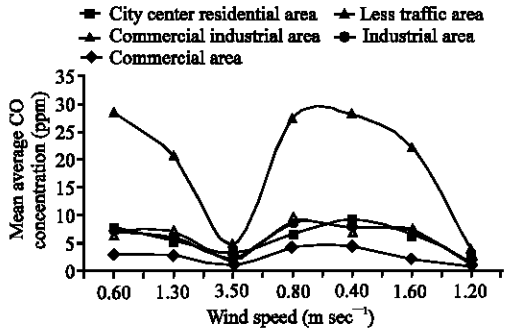

Fig. 4: Annual mean average of CO concentration at different wind speeds

Figure 1 shows the annual morning and afternoon mean average of measured wind speeds with error amount of 5% and represent that during weekdays, wind speed magnitude is higher in the morning rather than in the afternoon. Figure 2 clearly shows there is a positive relationship between CO concentration inside the taxi cabin and its age. It seems that the decreasing in the city transportation in the end of the week (Thursday afternoon and Friday), along with high wind speed were two effective factors to lower concentration of CO in the different areas in Kermanshah city (Fig. 3). The Fig. 4 clearly shows the effect of wind speeds on decreasing of the CO levels in the atmosphere at all stationary stations. This effect is not noticeable for wind speed below 1.5 m sec^{-1} but it strongly decreases the CO concentration levels in the city atmosphere at speeds of higher than 2 m sec^{-1}.

DISCUSSION

The results of this study showed that the annual mean value of CO concentration for both morning and afternoon measurements at 1120 stationary stations vary from 2.22-13.00 ppm with Standard Deviation (SD) of 0.03-0.40 for less traffic and commercial areas respectively, whereas measurement results in 1120 mobile stations were found to be 39.13 ppm with SD of 4.01 (Table 1). Seasonally minimum CO averaged concentration was observed in less traffic area stations in summer (2.00 ppm, SD = 1.18). The lower mean value of CO concentration in the summer may be due to higher wind speeds in this season. The maximum level of CO concentration was observed for both stationary and non-stationary stations in winter with mean value of 16.5 ppm and SD of 1.22 and 40.08 with SD of 10.61, respectively (Table 1).

Comparison between the mean averages of CO concentration at different seasons as shown in Table 1 clearly represents that CO concentrations in mobile stations are higher than stationary stations and they are in good agreement with the obtained results by previous workers (WHO, 1999; EPA, 1998; Godin *et al*., 1972; Von Burg, 1999; Maynard and Waller, 1999). High traffic density and atmospheric inversion at winter could be the cause of the higher CO concentration levels in commercial area. In all stationary stations, the afternoon CO concentration mean values (except in Thursday and Friday) were higher than those in the morning (Table 2) and this may be due to relative accumulation of pollutants in the city atmosphere and rush hour in the afternoon. Seasonally averaged CO concentrations levels in all non-stationary stations are higher than 30 ppm and vary from 33.04 (SD = 7.12) in winter to 42.36 ppm (SD = 6.35) in spring which they are in noticeable levels of CO pollution inside of the taxi cabin. This is may be as a result of self contamination process inside taxis. High level of CO concentrations inside taxi cabin is due to entering exhaust gases from back of vehicle by suction forces created in relative high speeds. It should be noted that direct relationship between taxi speed and CO concentration level especially in sudden braking with peak level of CO concentration of 85 ppm was observed. The other

Table 1: Seasonal and annual mean average and standard deviation of CO concentrations (ppm) in stationary and mobile stations at various parts of Kermanshah city

Location	Spring N = 560*		Summer N = 560*		Fall N = 560*		Winter N = 560*		Annual mean average CO concentration in stationary and mobile station (ppm), N = 2240	
Stationary station	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
City center residential area	4.20	0.31	3.42	0.20	4.39	0.27	4.83	0.41	4.21	0.09
Less traffic area (rural area)	2.42	0.14	2.00	0.18	2.25	0.13	2.21	0.20	2.22	0.03
Commercial area	10.83	0.44	11.12	1.33	13.57	0.90	16.50	1.22	13.00	0.40
Commercial- Industrial area	5.24	0.63	4.78	0.36	4.93	0.28	4.91	0.57	4.97	0.17
Industrial area	4.04	0.65	4.73	1.59	3.98	0.42	4.52	0.76	4.32	0.51
Mobile stations (inside taxi cabin)										
City center residential area	35.43	8.58	34.55	8.59	36.91	11.67	33.04	7.12	34.98	1.62
Less traffic area (rural area)	39.82	11.17	35.96	8.97	39.15	12.26	38.65	8.95	38.40	1.69
Commercial area	41.25	14.55	33.23	6.19	41.95	13.93	40.08	10.61	39.13	4.01
Commercial- Industrial area	42.18	12.33	35.91	9.93	38.43	10.87	36.26	9.85	38.20	2.88
Industrial area	42.36	6.35	35.12	8.40	39.07	11.26	36.36	9.47	38.23	3.21

* N = 56 for any separate location in stationary and mobile station

Table 2: Annual mean average of CO concentrations (ppm) during weekdays in different stationary stations at Kermanshah City

	Week days					
	Saturday		Sunday		Monday	
Station location	am	pm	am	pm	am	pm
City center residential area	4.00 (0.71)	5.24 (1.02)	3.68 (0.48)	5.22 (0.53)	3.88 (0.50)	5.08 (0.73)
Less traffic area (rural area)	2.28 (0.47)	2.49 (0.37)	1.80 (0.3)	3.18 (0.5)	1.80 (0.28)	3.01 (0.54)
Commercial area	13.79 (1.83)	17.31 (1.95)	10.98 (1.32)	18.49 (2.45)	11.43 (1.73)	14.67 (2.81)
Commercial-industrial area	5.49 (0.47)	4.82 (2.02)	4.43 (0.38)	7.29 (0.47)	4.33 (0.25)	6.39 (0.52)
Industrial area	4.21 (0.51)	4.22 (2.28)	3.56 (0.48)	6.08 (0.73)	3.59 (0.41)	4.24 (0.24)
Total mean Average	5.95 (0.8)	6.82 (1.53)	4.89 (0.59)	8.05 (0.93)	5.00 (0.63)	6.68 (0.97)

	Week days							
	Tuesday		Wednesday		Thursday		Friday	
Station location	am	pm	am	pm	am	pm	am	pm
City center residential area	3.38 (0.44)	6.12 (0.72)	3.5 (0.85)	6.36 (0.91)	2.95 (0.34)	4.97 (0.81)	1.9 (0.37)	1.98 (0.42)
Less traffic area (rural area)	1.81 (0.28)	3.74 (0.38)	1.86 (0.37)	3.45 (0.66)	1.32 (0.36)	2.37 (0.59)	0.83 (0.39)	1.20 (0.59)
Commercial area	11.54 (1.09)	18.24 (1.16)	13.72 (2.53)	20.41 (2.27)	9.15 (1.55)	13.42 (1.22)	4.28 (1.16)	4.2 (0.85)
Commercial-Industrial area	4.64 (0.56)	7.97 (0.45)	4.99 (0.6)	8.66 (0.56)	3.90 (0.42)	5.43 (0.45)	1.75 (0.21)	1.5 (0.35)
Industrial area	3.23 (0.36)	6.81 (0.24)	3.99 (0.62)	6.04 (0.31)	2.74 (0.54)	4.55 (0.55)	0.98 (0.21)	3.48 (2.25)
Total mean Average	4.92 (0.55)	8.58 (0.59)	5.91 (0.99)	8.98 (0.94)	4.01 (0.64)	6.15 (0.72)	1.95 (0.47)	2.47 (0.89)

parameter which could be able to increase CO concentration level inside of the taxi cabin is the taxi age. It was found that the older taxis had higher levels of CO concentration inside their cabins and no obvious differences were found among different seasons (Fig. 2). However, based on the fluctuations CO level trends taxis ages more than 10 years as investigated in this study, it could be expected that by increasing taxis ages older than 10 years in each year, CO concentration levels inside taxis cabin will be increased by 5%.

It is worth mentioning that Peykan brand taxis which are prevalent in Iranian cities as studied in this work, have an old and inefficient technology in fuel burning.

CONCLUSIONS

The results of this study clearly showed that considerable exposure to high levels of CO concentrations are existed in taxis cabins and commercial area that are highly exceeded from recommended standard level (more than 3 times of 8 h threshold, established by EPA). Also the old taxis in the city transportation system could expose their drivers and passengers to higher level of CO concentration which it may cause adverse effects on their heath. The optimum age for Peykan brand taxis may be 10 years, because by increasing the taxi age from 10 to 21 years, CO concentration level inside the taxis cabins goes up rapidly at least by 50%. Finally, findings of this study clearly showed that the main source of high levels of CO concentrations in Kermanshah as a non-industrialized city is traffic. Hence the main force to decrease the citizens exposure to the CO level must be focused on improving public transportation, traffic and renew the fleet.

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