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ORIGINAL ARTICLE

Occupational Exposure to Carbon Monoxide of Taxi Drivers in Tehran, Iran

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ABSTRACT

Occupational exposure to carbon monoxide (CO) of taxi drivers has seldom been evaluated in Iran. Accordingly, in-vehicle CO levels were evaluated during 6 months inside the taxis between May 2009 and October 2010. The CO concentrations of 36 personal samples were collected using a direct reading instrument equipped with electrochemical sensor. The arithmetic mean of the personal monitoring CO levels was 19.84 ± 4.24 ppm per day, with a range of 13.29-33.46 ppm. The observed concentrations of CO fell well lower than occupational standards. Exposures to CO during traffic flow in the evening were considerably higher than those measured in the morning. The weekdays, months and atmospheric environment had a significant effect on exposure to CO ($p< 0.0001$). The average CO level was 19.84 ± 4.24 ppm, which was higher than the outdoor CO levels (3.21 ppm). In conclusion, the penetration of outdoor CO pollution and engine combustion/exhaust infiltration constituted the main sources of the taxis drivers' personal exposure to CO.

Keywords: *Taxi drivers, Exposure, CO, Iran*

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INTRODUCTION

Sulfur oxides (SOx), nitrogen oxides (NO_X), lead (Pb), ozone (O_3), volatile organic compounds (VOCs) such as benzene, various kinds of particles (PM), polycyclic aromatic hydrocarbons (PAHs) and carbon monoxide (CO) are among dangerous toxic materials which exist in polluted air of many metropolis and threat people health [1-3]. In fact, air pollution is a disaster that many modern societies are dealing with them [4]. Air pollution causes various kinds of disease, mortality and high medicine expenses [5-7]. According to the world health organization (WHO) assessment; 2 million people die untimely every year due to the air pollution while more than half of these cases are devoted to developing countries [8].

Increasing in hospital admissions, effects on cardio-vascular, and respiratory systems, and reproductive disorders are among hurtful effects of this disaster [9-14]. Meanwhile, it should not be ignored the fact that cardio-vascular, respiratory and diabetes patients, pregnant women, senile people and kids are more vulnerable than the others [5,15,16].

There are different sources that cause such pollution crisis [17, 18]; however, according to studies the main source is motor vehicles [19, 20]. Considering the modern world, transportation is an unavoidable fact and in spite of the fact that people do not spend much time in traffic. According to the results of a research, people spend about 7% of their time in vehicles; however, it is

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Table1. Carbon monoxide concentration in taxis

Carbon Monoxide (ppm)	Number	X±SD*	Min	Max
The CO in every 30 seconds	10582	19.81±10.26	2	18.7
The CO in each sampling day	36	19.84±4.24	13.29	33.46

* Standard deviation

possible to be exposed to carbon monoxide to high extent [18-21].

It is obvious that people who, have to spend more time in such microenvironment because of their jobs are more susceptible to dangerous effects of air pollution. Persons who work in transportation system are examples of such people who expos to high levels [22].

CO is one of the main sources of air pollution which is the result of incomplete burning of carbonic material especially fossil fuels [3]. As noted above, CO is colorless, odorless, and tasteless gas which is rather stable in the air. CO is one of the main traffic-related air pollutants which is considered as a significant factor in public health and is dangerous even in low concentration [23]. It goes to the bloodstream and causes body's organs and tissues to absorb less oxygen [3]. Motor vehicles mainly cars are the principal sources that emit this pollutant to the air [9].

Tehran is one of the polluted metropolises in developing world which experiences serious pollution problems because of its geographical and weather conditions. The surrounding mountains in north and west, local weak winds, main winds from west, south and southwest which are industrial places are the main sources of Tehran air pollution. In addition, the city experiences temperature inversion phenomena 250 days a year that strengthen the pollution [24]. While there are 3.5 million cars in Tehran [25], about 71% of Tehran air pollution is the result of the mentioned mobile sources [20].

This study aimed to measure the concentration of CO in taxis' cabins to investigate to what level taxi drivers and passengers are exposed to this toxic pollutant. In addition, since there is some evidence that fixed site stations does not show the exact exposure concentration to the pollutant [26-29], we compared the level of the pollutant which was registered by these stations with the measured level of CO in the taxis.

MATERIALS AND METHODS

Study design and subject

This cross-sectional study was done from May 2009 to October 2010 in Tehran, Iran, a major urban city of 8000000 population. The study involved 36 male taxi drivers (age 41.83 years old; 6.89 working years in average) occupationally exposed to traffic-related air pollutant (CO). All the taxis were petrol fuelled and had not air-conditioning systems. Regarding the expanse of Tehran, an area (31988104 m²) in downtown which is recognized as traffic restrict was considered as sampling locations (in this area, cars are not permitted from 6.30 a.m. to 5 p.m. without justification). The 16 main paths include 7 east-west and 9 north- south were investigated randomly in each sampling day (Fig. 1).

Sampling design and equipment

The sampling was carried out in taxis (N= 36) every last week (6 days, from Saturday to Thursday) of six months (36 days totally) from approximately 9 a.m. to 1:00 p.m and 4 p.m. to 8 p.m. To measure the CO concentrations, the first check 5000+ portable gas analyzer system which is made in England - ION Science Company was used in combination with an electrochemical sense mechanism that is able to measure 1-10000 ppm concentration of CO. It also measure the air with 220 ml/min (flow rate) and shows CO's level instantly. Moreover, standard cylinders which include definite concentration of CO were used in calibration with the company suggestion.

Fig. 1. The study area and the locations of measurements

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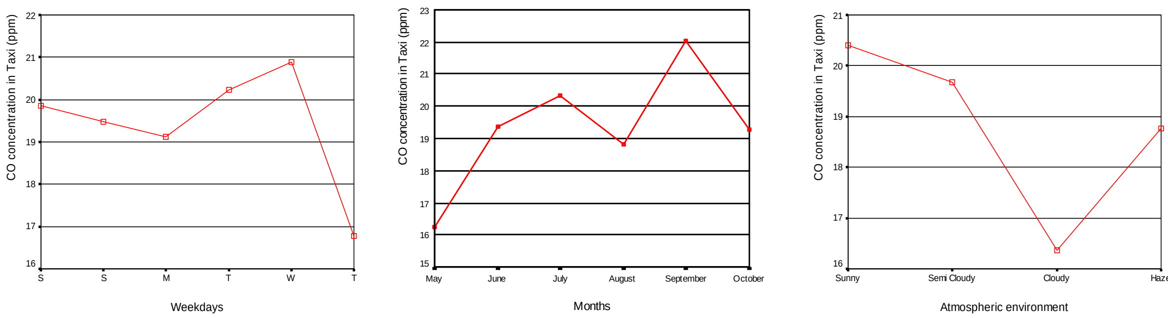

Fig. 2. CO concentration (ppm) in taxi according to A: weekdays B: months C: atmospheric environment

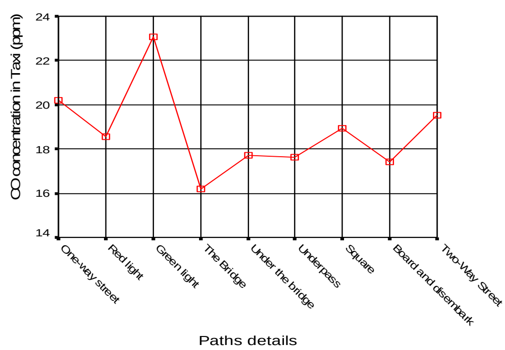

Fig. 3. CO concentration (ppm) in taxi according to path details

The taxis traveling on in-use traffic restrict were selected randomly and all drivers participated in the study voluntarily. Before the shift, the study was explained to the subject, equipment operation was explained and a signed consent form was obtained. A brief questionnaire was administered to the subject. Basic information such as age, occupation, education, smoking, taxi and self-reported work-shift traffic density were included in the questionnaire.

Hourly average of in-vehicle and outdoor temperature, RH%, and wind speed were measured and obtained from the Tehran air quality control company, respectively.

Data analysis

The air sampling data were further categorized based on the paths (with 9 details), atmosphere environments, months and weekdays. All the statistical analysis, including descriptive analysis, *t*-test and one-way ANOVA for analysis of the effect of those variables on the measures pollutant levels were done in SPSS 13.5 (SPSS, Inc, Chicago, IL). $p<0.05$ was considered statistically significant

RESULTS

In-vehicle CO levels

The arithmetic mean and range values of CO in the personal samples have been presented in Table 1. As summarized in table 1, the minimum and maximum concentrations of CO (13.29 and 33.46 ppm) were found in the end of each sampling day. The overall average in-vehicle CO level was 19.84 (4.24) ppm during six months. As the results show, all of the drivers were exposed to CO lower than the WHO 1-h AAQ guideline and also ACGIH TLV for 8-h, which are 30 and 25 ppm, respectively. As mentioned above, the air sampling was done in morning and evening in each sampling day alternately. Independent Samples t- test was used for evaluating the amount of drivers' exposure to CO. The arithmetic mean of CO concentrations were significantly higher in the evening (20.32 ppm) than in the morning (19.25 ppm) ($p<0.0001$).

Weekdays and CO levels

Fig. 2a presents the various concentration profiles obtained for the vehicles on weekdays. As the results shows, the minimum concentration on Thursdays (16.69 ppm in average) and the maximum was on Sundays and Wednesdays (21.33 & 21.83 ppm respectively). On-way analysis of variance test was used for studying the effect of this variable (weekdays). Results showed a significant difference in CO exposure levels on different weekdays ($p<0.0001$).

In-vehicle CO level to Months relationship

Fig. 2b also depicts the various levels profiles obtained for the vehicles on different months. One-way ANOVA test was also conducted to see whether there was difference in exposure amount in different months of year ($p<0.0001$). The minimum concentration belonged to May (16.19 ppm) and the maximum was obtained for September (22.96 ppm).

Atmospheric environment and CO levels

Weather condition was divided to 4 kinds during sampling days in the study: sunny, semi cloudy, cloudy, and haze. Once again, ANOVA test proved a significant difference among various mentioned climate ($p<0.0001$). In the sunny days the existing CO inside Taxis approached its maximum concentration (20.41

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ppm) and in the cloudy days it became the minimum concentration (16.36 ppm) (Fig. 2c).

Relationship between the CO and paths details

The relationships between CO concentrations and the paths details (traffic light, squares, some streets, bridges) indicated that CO levels were positively correlated with districts and some special places in paths ($p<0.0001$). The maximum exposure level (23.07 ppm) was observed at the moment that the drivers were starting to move again after stopping before traffic lights. The minimum amount (16.21 ppm) was obtained on bridges (Fig. 3). No more considerable difference was observed in the bridges ($p=0.235$).

Outdoor and in-vehicle CO levels

Outdoor air characterization included CO monitoring in the 13 stations for 36 days during the six months. The average concentration of these data was 3.21 ppm for the city. The minimum and maximum concentration were (2.07 & 4.15 ppm respectively) for this period of time. Considering all details of data obtained from these stations (hourly data), the maximum concentration of CO in the city was 14.83 ppm in 6 months.

In-vehicle CO levels to metrological conditions

The backward regression analysis was used to determine the relationship between occupational exposure to CO levels and wind speed, humidity, and weather condition. As the results show, the external variable which affects the exposed levels of CO, humidity ($p=0.008$) and wind speed ($p<0.0001$) were more effective.

DISCUSSION

Occupational exposure to the CO on-board of the vehicles has been rarely evaluated in Iran. As it was mentioned, the average of CO concentration in taxis was 19.84 ppm which is actually considered as high amount; however, it expectable in 2 reasons: first, closed and restricted chamber in car cause pollutant aggregation. Second, vehicles are the main sources of air pollution, so, it leads to high exposure level to CO in taxis. Due to the fact that sampling was done in heavy traffic in determined areas and considering that in conducted researches, the cars' indoor air pollution was attributed to surrounding cars near them [30]. The more crowded the streets with cars, the more air pollution was observed. In a study, increasing the numbers of cars (1000-5000) caused 71% increase in CO [31]. In current study, the concentration of CO approached 187 ppm in some cases. Many studies in other countries also reported high exposure concentration in cars' cabins.

Chan and his colleagues reported 18.7 ppm exposure to CO in taxis without air-conditioner [32]. Abi Asber and his colleagues compared exposure to CO in and out of cars and declared that this amount is 7- 40 ppm in cars [33]. This was also claimed to be 15.7 & 21.4 ppm in Vietnam and Greece respectively [27,34].

As the results showed, taxi drivers who work in evening are exposed to the higher concentrations of CO. In contrast, other studies claimed more exposure in the morning [26-28] and they attributed this result to more crowded street in morning in their studies. There are some reasons for this different result in the current study and others. First, there were more vehicles in the evenings in studied district. Because the district was a forbidden one for without justification cars in some hours, so, there were fewer cars from morning till 5 p.m. and after 5 p.m. more cars were driving in these districts. In fact, a part of sampling was in evening. As a result, more cars in the evening caused more air pollution. The second reason can be attributed to more humidity in mornings. It was 18.6% in morning, however, 14.71% in the evening ($p=0.001$). The correlation test of humidity amount and in car air pollution represented an indirect result, meaning that by increasing the humidity, the amount of CO pollution is decreased.

It is interesting to note that, the personal exposure to CO was different on weekdays. Maximum concentration devoted to the initial and final weekdays. At the beginning of week, people start their activity. Habitants' moving on streets on one hand and 1 million people commuting to Tehran every day [24] on the other hand result in heavier traffic and consequently higher concentration of CO. Considering the fact that most of the educational centers and offices are closed on Thursdays or at least working hours are less than other days', Wednesdays as the last working days experience heavy traffic and consequently more air pollution in contrast to Thursdays.

Congruent with previous study, this study confirms that, taxi drivers have a higher occupational exposure to CO in days prior to weekend [35].

As noted in Fig. 2.b, air pollution is a rising process during the study in sequencing months. It can be justified by referring to humidity and wind speed. While, the authors were conducting the research in 6 months, humidity and wind speed were falling continuously during 6 months. Furthermore, the results indicated that CO concentrations were positively correlated with the 2 variables. The correlation coefficient was -0.265 ($p<0.0001$) between humidity and air pollution and -0.361 ($p<0.0001$) between wind speed and air pollution. In similar to this study, Gmez-Perales et al. (2004), Kim et al. (2005) and Kaur et al. (2009) reported a significant relationship of in-vehicle CO with wind speed [26, 35, 36]. Similar strong relationship between CO exposure and wind speed was previously identified by Zagury et al. (2000) [31].

Due to the fact that sampling was done in last days of months, heavier traffic and consequently, more air pollution was observed in September. The reason was that in last days of this month people come back from their trip and also because schools are going to open again, families tend to go shopping. Meanwhile decreasing air pollution in August can be referred to coinciding to Ramadan (special Muslims month) in which working hours is changed to some extent.

As mentioned above, sampling was carried out during a calendar year, under different climatic

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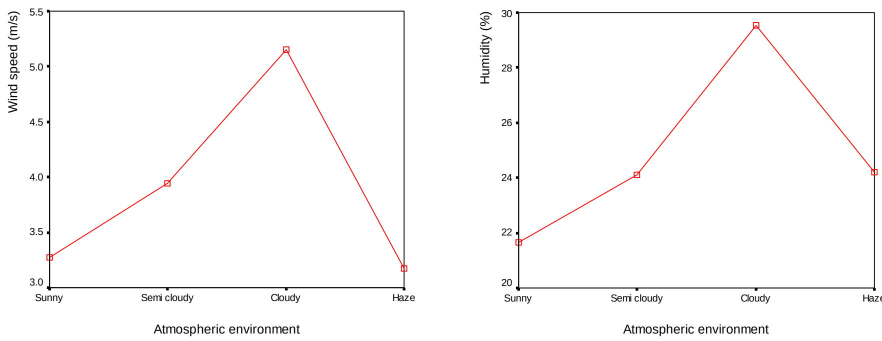

Fig. 4. Relationship between Atmospheric environment and A: wind speed B: humidity

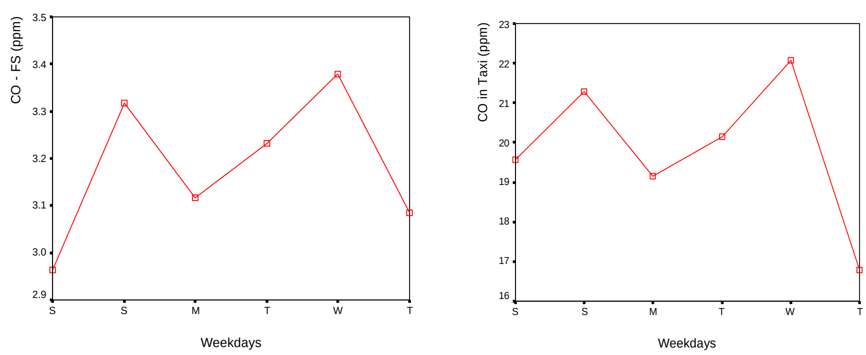

Fig. 5. CO concentration (ppm) according to weekdays in A: Fixed site Station (FS) B: Taxi

conditions. Occupational exposures to CO levels were compared for sunny and cloudy days. Results showed that mean exposure to CO was significantly higher on cloudy days than mean exposure to CO levels on sunny days (Fig. 4). As it can be seen in the following diagrams, humidity and wind speed approaches their minimum amount in sunny days and reaches the maximum point in cloudy days.

As it was mentioned in the results, the most exposure to CO was observed at the starting moment after stopping before red light. When the car stops, the engine does not work for moving, so, there is not high levels pollution; however when it starts as the light turns to green, increasing air pollution will result. On bridges, decreasing air pollution was observed since there is no car crowd in these open environments. In fact the significant role of canyons located between high buildings in increasing contaminants' concentration should not be ignored [34, 37].

As it was declared in results there is a great difference between in and out of cars CO levels. Earlier studies invariably indicated similar results [27, 29]. Other studies in Mexico City, England, and France also declared the same results [26, 29, 31]. The correlation test between CO concentration in taxi and out of it did not show high correlation (0.265, p = 0.118). It should be taken into account that CO concentration pattern is mostly the same for all weekdays for both cases (Fig. 5). The time of sample can be reason for low correlation; also, exposure pattern is not similar in different months which show that there is difference between being exposed to CO in and out of taxis.

Meanwhile, the fixed stations are located far from streets in which there are lots of vehicles which are main sources of air pollution, so, naturally by being farther from streets there would be less air pollution. Moreover the height in which the air is analyzed is higher than people breathing zone, as it was previously mentioned air pollution is less on bridges which are located in higher level than streets. Besides, air contaminants aggregation in cars' closed chamber should not be ignored which is one of the reasons for being exposed to air pollution to high concentration [27]. Finally, the methodology which is used by these stations and records information by their average in an hour can not be used as a reliable mean for comparing resulted data directly and this again can be among the reasons [28].

Compared to other studies

The average level of exposure to CO was measured 19.84 ppm in current study. As it was shown in Table 2, some studies showed the same results as this study and some others do not. Several reasons cause these differences such as: Traffic condition, vehicles' technology, climate and geographical condition, vehicles' lifetime (age), kind of fuel they use, sampling process, and environmental principles [31, 38-41].

CONCLUSION

In conclusion, exposure to CO was generally higher in- vehicle which is constructed in developing countries than in similar monitoring in developed countries. The examination of in-vehicle CO exposure in Tehran for

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Table 2. In-vehicle mean concentration of CO for the present and other studies

Study	Year	Location	Sampling type	Subject	CO (ppm)
Current study	2010	Iran-Tehran	Electrochemical sensor	Taxi	19.84
Chan [32]	2002	Guangzhou-China	Electrochemical sensor	Taxi without air-conditioner	18.7
				Taxi with air conditioner	28.7
				Bus without air- conditioner	8.2
				Bus with air conditioner	8.9
				Subway	3.1
Saksena [34]	2008	Vietnam- Hanoi	Electrochemical sensor	Car	18.5
				Bus	11.5
				Motorcycle	18.6
				On-foot	8.5
Abi [33]	2007	Lebanon- Beirut	Electrochemical sensor	Taxi	7 – 40
Duci [27]	2003	Greece-Athens	Electrochemical sensor	Personal car	21.4
				Bus	10.4
				Trolley	9.6
				Electrical train	4
				On-foot	11.5
Kaur [36]	2009	England-London	Electrochemical sensor	Taxi	1.2
				Car	1.3
				Bus	0.8
				Bicycle	0.9
				On-foot	0.7
Zagury [31]	2000	France-Paris	Electrochemical sensor	Taxi	3.8
Xlanglu [42]	2005	Peru-Trojilo	Electrochemical sensor	Taxi	0.87
				Bus	0.24
			Detector tube	Taxi	3.1
				Bus	2.36
Gomez [26]	2004	Mexico city	Electrochemical sensor	Mini bus	15
				Bus	12
				Subway	7

taxis showed that CO levels were high compared to results obtained by other similar studies (Table 2). Concomitant outdoor CO monitoring showed that occupational exposure to CO in taxis are in general dependent on surrounding traffic condition and engine combustion/exhaust infiltration. Comparison of results of date and paths details revealed that, car-exterior is not the only source on in-vehicle CO. In general, in-vehicle CO levels, as well as the 8-TWA concentrations, were lower than the applicable WHO and ACGIH occupational standard. Improvement in engine design for control of air-to-fuel and compression ratio, the use of short-term measures include improvement of public transit, management of parking and pricing, enforcement of vehicle inspection programs and improvement in fuel quality are strongly recommended.

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