Atmospheric Pollution Research 6 (2015) 550-555

Atmospheric Pollution Research

www.atmospolres.com

Concentrations of carbon monoxide in indoor and outdoor air of Ghalyun cafes

Mehdi Fazlzadeh [1], Roohollah Rostami [2], Sadegh Hazrati [1], Ali Rastgu [1]

[1] *Department of Environmental Health Engineering, School of Public Health, Ardabil University of Medical Sciences, Ardabil, Iran*
[2] *Department of Environmental Health Engineering, School of Health, Semnan University of Medical Sciences, Semnan, Iran*

ABSTRACT

Indoor and outdoor carbon monoxide (CO) concentrations were measured in 68 Ghalyun cafes in Ardabil City of Iran. One hour sampling was performed in each location and hourly mean concentrations were reported. Respective mean concentrations of CO in indoor and outdoor air were 24.75±17.17 and 2.65±1.33 ppm with an average indoor to outdoor air concentration ratio of 13.3±13.1. Within the variables studied; type of the tobacco smoked, location of the cafe inside the building, and utilizing mechanical ventilator, respectively, were recognized as the most influential factors controlling CO concentrations in Ghalyun cafes ($p<0.05$). 73.5% of workers (27.3 and 95.7% of cafes located on ground floors and basements, respectively) were exposed to higher levels of CO than the corrected OEL–TWA (Occupational Exposure Limit) of 10.4 ppm.

Keywords: *Carbon monoxide, Ghalyun, indoor, outdoor, cafes*

Corresponding Author:
Sadegh Hazrati
☎ : *+98-4533513428*
🖷 : *+98-4533512004*
✉ : *S.hazrati@arums.ac.ir*

Article History:
Received: 05 July 2014
Revised: 16 December 2014
Accepted: 18 December 2014

doi: 10.5094/APR.2015.061

1. Introduction

CO is a colorless, non–irritating, odorless, and tasteless gaseous pollutant (Langston et al., 2010) that may be emitted into the environment from anthropogenic or natural sources. It is produced by incomplete combustion of carbonaceous fuels such as wood, petrol, coal, natural gas and kerosene (WHO, 2010). Motor vehicles and industries are recognized as main sources for atmospheric CO pollution in urban areas. However, indoor air quality may be affected by wide variety of CO emitting sources including gas stoves, tobacco smoke, wood burning stoves, fireplaces, and other fossil fuel burners (Chowdhury et al., 2013). Exposure to the high concentrations of CO in indoor ambient air at home is rare and limited to some particular conditions like being close to CO emitting sources (Chaloulakou and Mavroidis, 2002). CO concentration in indoor air doesn't normally exceed 30 ppm under regular conditions with sufficient natural ventilation and air exchange rates (ATSDR, 2009). For indoor environments with no CO emitting sources, indoor concentrations in homes, schools, and offices will be relatively similar to and influenced by outdoor CO concentrations (Zhong et al., 2013) with indoor to outdoor (I/O) ratios generally around 1 (WHO, 2010) .

Exposure to CO leads to various health effects through affecting cardiovascular system, lungs, and blood and central nervous systems depending on health and physiological status of exposed person, pollutant concentration, and exposure time (WHO, 2010; Reboul et al., 2012). One of the important outcomes of exposure to CO is reaction with blood hemoglobin molecules to make carboxyhemoglobin (COHb); reducing oxygen supply to brain and other body organs. COHb concentration in blood has been utilized as an indicator for health consequences of exposure to CO and various symptoms have been linked to different concentrations of COHb in blood (COHb%). In general, signs and symptoms of acute CO poisoning appears at COHb concentrations ranging from 3 to 24%. It is stated that the symptoms of exposure to CO appears in COHb% more than 3 percent in blood (ATSDR, 2009).

In order to prevent health risks, many organizations have set guidelines or standards for CO exposure. Occupational Safety and Health Administration (OSHA), National Institute for Occupational Safety and Health (NIOSH), and Iran Health Ministry have recommended time–weighted permissible exposure limit (PEL–TWA) of 50 ppm, recommended exposure limit (REL–TWA) of 35 ppm, and occupational exposure limit (OEL–TWA) of 25 ppm for occupationally exposed workers, respectively (MHMEI, 2012; NIOSH, 2012; OSHA, 2012). A TWA is the average exposure over a specified period of time, usually a nominal eight hours. U.S. National Ambient Air Quality Standard and Iran environmental protection organization (IEPO) have set limits of 9 ppm for 8 h and 35 ppm for 1 h exposure periods as the primary standards and WHO has recommended 8 ppm for 8 h and 28 ppm for 1 h for CO concentrations in ambient air (WHO, 2010; IEPO, 2012; U.S. EPA, 2013).

Extensive reports have been published on CO concentrations in ambient air as well as some industrial establishments (Naeher et al., 2000; Chaloulakou and Mavroidis, 2002; Chaloulakou et al., 2003; Jo and Lee, 2006; Zhong et al., 2013); however, its concentrations in public microenvironments has less been documented. One of the most important public indoor microenvironments that pose potential for elevated CO concentrations are Ghalyun cafes. These establishments are run around the country in Republic Islamic of Iran, where Ghalyun (also known as hookah, narghile, Shisha, Sheesha, Hubbly–bubbly, and Waterpipe in different countries) is served for customers. Ghalyun smoking is a common practice especially among youth, college students, and young professionals.

Ghalyun is used to smoke tobacco by directly/indirectly heating the tobacco, usually with burning charcoal. The smoke is filtered through a bowl of water and then inhaled through a hose (Knishkowy and Amitai, 2005). These practices that have recently been found extensive popularity worldwide, significantly affects air quality of the cafes where Ghalyuns are smoked. Preparation of charcoal (i.e. burning in fire places) and smoking of Ghalyun are major sources for CO emission at these environments, which may impose serious effects on employees' and customers' health.

Iran parliament did pass a prohibition law on smoking (ICARC, 1997) and health authorities have banned smoking (e.g. Ghalyun) in public environments (e.g. cafes) since 2007. However, it has less been taken in effect yet due to some social considerations.

To our knowledge there has been no data published on CO concentrations in Ghalyun cafes either in local or national level. In this research we aimed to survey CO concentrations in indoor and outdoor air of Ghalyun cafes in Ardabil city and to elucidate factors affecting its concentration in indoor air.

2. Material and Methods

Ghalyun cafes were studied for their indoor air pollution in Ardabil city, capital of Ardabil province located in North West of Islamic Republic of Iran. The city is located in latitude and longitude of 38.2500°N and 48.2833°E. Of 236 cafes, 68 were selected using random sampling method (Figure 1). Concentrations of CO in indoor and outdoor air were measured at breathing zone (i.e. 150 cm above the ground) using a portable gas meter (Honeywell BW MAX XTII, Brandt Instruments, Inc. Canada). Measurement of CO concentrations at each sampling location was continued for one hour and the concentrations displayed on the gas meter screen were written down in a 2 minute intervals and arithmetic average of 30 readings was reported as the CO concentration for each location. Measuring range of this instrument was 0–1 000 ppm with a precision of ±1 ppm. It was calibrated before the sampling campaign. The outdoor sampling was carried out at the same time as the indoor sampling, with the outdoor ambient sites less than 50 m from each sampled cafe. The measurements were performed from noon to evening in summer. Other variables including; the floor that cafes were located on (i.e. basement/ground floor), ventilation system, type of the tobacco smoked (i.e. traditional or fruit flavored), and employees information were collected using a self–designed questionnaire. Concentrations of CO in indoor and outdoor air were compared with occupational standards for the cafe workers and ambient air quality standards for the patrons (i.e. WHO, 2010; IEPO, 2012; MHMEI, 2012; NIOSH, 2012; OSHA, 2012; U.S. EPA, 2013). Data were analyzed by *t*–test, correlation coefficient, Kolmogorov–Smirnov, and nonparametric tests such as Mann–Whitney and Wilcoxon for comparing the CO concentrations between cafe floors, kind of tobacco, ventilation systems, indoor and outdoor concentrations, and comparing the concentrations in each group with normal distribution using SPSS version 16. Confidence level was set at 95%.

3. Results

CO concentrations in indoor air followed normal distribution (p=0.144), though it was not the case for outdoor air values (p=0.017). Therefore, *t*–test and Mann–Whitney test were applied to compare CO concentrations between two groups. The results obtained for indoor and outdoor air monitoring of Ghalyun cafes are summarized in Table 1 and Figure 2.

The concentrations of CO indoors were significantly higher than outdoors, with average indoor/outdoor concentration ratio (I/O) of 13.3±13.1 (Table 1). We also found no statistically significant correlation between indoor and outdoor CO concentrations (R=–0.198, p=0.105).

CO concentrations in indoor air of cafes varied from 6.1 to 112.4 ppm with a mean concentration of 24.8 ppm. Also, there was a significant difference between outdoor concentrations in type of tobacco category (p=0.045) and outdoor concentrations were slightly higher for traditional tobacco used cafes. Mean CO concentration in outdoor air for all the monitoring locations was estimated as 2.7 ppm, ranging from 1 to 6 ppm.

Two types of tobacco (traditional and fruit flavored tobacco) are smoked in Ardabil cafes. CO concentrations were significantly higher in flavored Ghalyun smoking cafes than those of traditional tobacco users (Table 1).

Most of monitored cafes were located in basement. Indoor air quality in the cafes was also affected by the floors they were located on (*t*–test, p<0.0001) and elevated CO concentrations were found where the cafes were operated in basement. However, comparing CO concentrations revealed no statistically significant differences between the cafes with natural and installed mechanical ventilation systems; nevertheless, maximum CO concentration in cafes without mechanical ventilation was much higher (112.4 ppm) than in cafes with ventilation (36.3 ppm).

Table 1. *Carbon monoxide concentrations (ppm) in indoor and outdoor air*

		Indoor Air				Outdoor Air				I/O Ratio
		Min	Average	Max	SD	Min	Average	Max	SD	
Type of Tobacco	Traditional (n=55)	6.4	8.8	13.4	2	1	3.3	5	1.3	3.2
	Herbal (flavored) (n=13)	6.1	28.5	112.4	17	1	2.5	6	1.3	15.7
	p		<0.0001				0.045			
Location of Cafes	Basement (n=46)	8.4	30.4	112.4	17.3	1	2.5	6	1.3	14.1
	Ground Floor (n=22)	6.1	12.9	35.2	9	1	3	5	1.4	5.2
P value			<0.0001				0.143			
Mechanical Ventilation	Yes (n=22)	8.1	22.4	36.3	8.4	1	2.9	6	1.4	9.8
	No (n=46)	6.1	25.9	112.4	20.1	1	2.5	5	1.3	14.4
	t–test, P value		0.325				0.282			
Total (n=68)		6.1	24.8	112.4	17.2	1	2.7	6	1.3	13.3
Wilcoxon test, p value						<0.0001				

Figure 1. *Selection of the measurement locations in Ardabil City.*

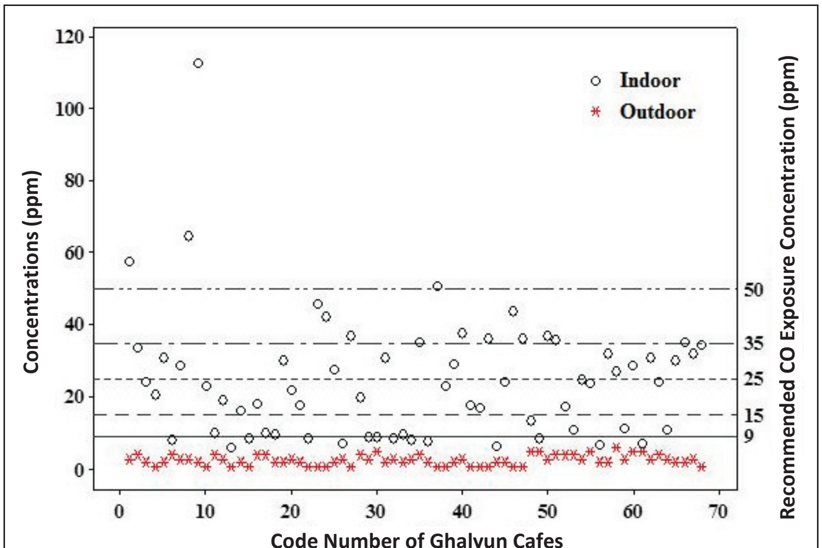

Figure 2. *CO concentrations in Ghalyun cafes and recommended exposure limits.*

CO indoor concentrations in 42.6% of the cafes were higher than the occupational exposure limit recommended by Iran Health Ministry (i.e. 25 ppm) (Table 2). The CO levels found at all the outdoor sampling sites were lower than that of IEPO recommendation (i.e. 9 ppm).

For the non–smoker patrons and employees who had exposure to CO in the cafes, the COHb% can be estimated by Peterson and Stewart equation [Equation (1)] (Chaloulakou et al., 2000). The concentrations were assumed to be constant as the obtained average values during the modeling period. According to the concentrations quantified for the cafes, mean COHb% for 1 and 8 hours of exposure to CO in the cafes are estimated to be 1.02%±0.6 and 3.8%±2.22, respectively (Figure 3).

$$\text{Log}(\text{COHb}\%) = 0.858 \times \log(\text{CO}) + 0.63 \times \log(t) - 2.295 \quad (1)$$

Table 2. *Proportion of Ghalyun cafes with CO concentrations above the recommended CO limits*

Recommended CO Concentration (ppm)	Proportion (%)	Authority
≥9	79.4	U.S. EPA (2013); IEPO (2012), Ambient air (8 h)
≥25	42.6	MHMEI (2012), (OEL–TWA)
≥28	39.7	WHO (2010), Ambient air (1 h)
≥35	22	NIOSH (2012), (TWA); IEPO (2012), Ambient air (1 h)
≥50	5.3	OSHA (2012), (REL–TWA)

4. Discussion

4.1. CO concentrations in outdoor and indoor air

CO concentrations in outdoor air are appreciably lower than the concentrations recommended by national and international organizations as well as the results reported for major cities in Iran (Ahmadi Asoor and Allahabadi, 2011; Dehghanzadeh et al., 2013). This might be due to the fact that there are no major industrial sources for CO emissions in Ardabil and traffic congestion is also relatively lower within the city compared to other major cities. It seems that, the slightly higher outdoor CO concentrations at the cafes where traditional tobacco were used were due to the fact that they are located in the city center, which is typically a region with more traffic than other regions of city. The relationship between traffic and ambient CO concentrations is well known from the previous researches. It was reported that the CO concentration was up to 150 ppm in ambient air of Tehran (capital of Iran) streets when the traffic was heavy (Rashidi and Massoudi, 1980). Also, Padro–Martinez et al. (2012) reported the correlation between traffic and air pollutants such as CO. Dehghanzadeh et al. (2013) reported CO concentrations up to 11 ppm in commercial parts of Tabriz (one of major cities of Iran) and up to 4.5 ppm in suburban parts of the city. Also, they found the I/O ration within 0.2 to 1.6 in Tabriz residential areas.

The results showed that CO concentrations are remarkably higher in indoor air of cafes (24.8±17.2 ppm) than outdoor atmosphere (2.7±1.3 ppm). Similarly, a high CO concentration (65 ppm) was reported in a study in ambient air of a room after a session of 4 hour waterpipe smoking (Fromme et al., 2009). Given the issues raised above, high I/O ratio of CO concentrations found in present study implies that infiltration of atmospheric CO to indoor environments is not the case for our study. This is in line with the findings of a study where CO concentrations in kitchen of restaurants were much higher than the outdoor air; implying presence of CO emission sources inside the indoor microenvironments (Ghasemkhani and Naseri, 2008). However, I/O ratios of CO concentrations found in the present study are higher than the values (i.e. 0.94–1.28) reported for homes and restaurants (Ghasemkhani and Naseri, 2008; Zhong et al., 2013), as well as the range of 0.2–4.1 reported for indoor microenvironments in the absence of any major indoor sources (WHO, 2010).

The main possible sources of CO identified for the cafes monitored are Ghalyun preparation process (i.e. coal lighting and burning), smoking practices, Samovars (a heated metal container used to heat and boil water), and gas stoves. CO is reported to comprise 0.34–1.4% by volume of hookah smoke (Sajid et al., 1993). CO concentrations found in indoor air of hookah cafes (i.e. 30.8 ppm) were significantly higher than the traditional bars (i.e. 8.9 ppm) where only cigarette was smoked (Burnett et al., 1997; Jacob et al., 2011). Hence, concurrently tobacco smoking in confined indoor environments appears to be the most important CO emission source in the present study.

4.2. Factors affecting indoor air CO concentrations

Among the different variables influencing indoor air quality; type of tobacco smoked, the floor in which the cafe was located on, and operating mechanical ventilation were studied. Various types of tobacco smoked produce different pollutants at different concentrations (Baker and Proctor, 1990; Ding et al., 2005). Indoor air quality in terms of CO pollution was significantly poor in the cafes where flavored tobacco was served. Our findings support the report where the type of tobacco smoked affected CO concentration in hookah cafes (Sajid et al., 1993). This might be interpreted through the time required to smoke Ghalyun with different type of tobacco. Ghalyuns containing flavored tobacco last at least 4 times longer to smoke than the traditional one. This may be due to the soft and tasty smoke of flavored tobacco as well as the tendency of youth customers to spend more time on smoking of this type of Ghalyun.

Other examined variable was the floor in which the cafes were located on. CO concentrations were significantly higher in cafes operated in basement (mean=30.4 ppm) than in ground floor (mean=12.9 ppm). Indoor air quality in the majority of latter cafes (i.e. 86.4%) met the OEL–TWA limit recommended by Iran Health Ministry. However, CO concentrations in more than 56% of basements exceeded OEL–TWA; highlighting the necessity to enforce environmental health regulations in such cafes. Most of the cafes were located on basement with poor and ineffective natural ventilation (i.e. 46 against 22 establishments) allowing very limited outflow of indoor air pollutants (Repace and Lowrey, 1982).

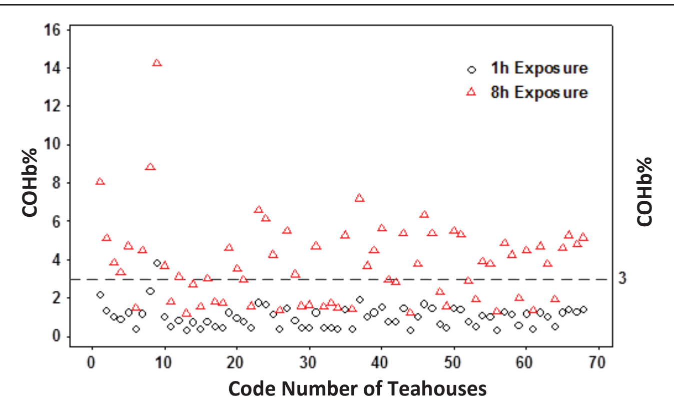

Figure 3. *Estimated COHb% for employees of Ghalyun cafes.*

The cafes equipped with mechanical ventilator displayed no statistically significant differences in CO concentrations comparing to those of naturally ventilated establishments. However, when we considered the combined effect of ventilation system employed along with the floor that the cafes were located on; then different picture emerged. Excluding the cafes located on ground floor because of the very small number of such establishments operating mechanical ventilators (i.e. 2 out of 22 cafes), CO concentrations were significantly lower in the cafes using mechanical ventilation systems than the ones not operating such ventilators (t–test, p=0.012). This finding implies that CO concentration can be reduced in such places effectively through simply operating mechanical ventilators.

Two scenarios may be considered for human exposure to CO in cafe microenvironments; occupational and general population exposures. In terms of occupational exposure, employees of more than 42.6% of the cafes are exposed to concentrations higher than OEL–TWA of 25 ppm set by Iran Health Ministry for 44 working hour in a week. It is important to note that the employees of the selected cafes in this study normally work for 12 hours per day and 6 days per week; i.e. 72 hours per week. Correction made for OEL concentration in this case based on Brief and Scala Model (Verma, 2000), which is a model for adjustment of recommended limit levels for unusual exposure times, gives a daily Reduction Factor of 0.42 and consequently corrected OEL–TWL concentration of 10.4 ppm. Comparing to the corrected OEL–TWA concentration revealed that 73.5% of workers (i.e. 27.3 and 95.7% of cafes located on ground floor and basement, respectively) occupationally exposed to exceeded concentrations of CO at the workplace.

Second scenario is relevant to customers who normally spend approximately one hour per day in cafes for socializing without smoking Ghalyun (i.e. drinking tea), although majority of patrons spend much higher time in such places. Comparing to the WHO guideline of 35 mg/m^3 (28 ppm) recommended for 1 hour (WHO, 2010), 39.7% of the customers are at risk of higher exposure to CO. Prolonged exposure to low concentrations of CO may result in serious health effects including cardiovascular problems (Satran et al., 2005; Weber et al., 2011). There is a potential for increased blood COHb% in Ghalyun smokers due to directly inhaled highly concentrated CO smoke through hose and mouthpiece. Cases of poisoning and syncope have been reported among hookah smokers at COHb% of 24–27% (Eissenberg and Shihadeh, 2009; Lim et al., 2009; Turkmen et al., 2011; La Fauci et al., 2012;). Thus, elevated CO concentration found in the cafes might also increase risk of CO poisoning among Ghalyun smokers. Average COHb of <3% was estimated for 1 hour exposure in the cafes; the level at which poisoning symptoms are appeared (ATSDR, 2009). However, assuming relatively constant CO concentrations for all working time, COHb was on average 3.8% for 8 hours exposure time.

5. Conclusions

Indoor CO concentrations are much higher than the recommended exposure limits at many sampling locations. Within the variables studied; type of the tobacco smoked, location of the cafe inside the building, and utilizing mechanical ventilators, respectively, were recognized as the most influential factors controlling CO concentrations in Ghalyun cafes. Therefore, enhancing air exchange rates through local exhaust and general ventilation systems along with applying restriction on operating the cafes located on basement may significantly reduce risk of both occupational and second hand exposure to tobacco smoke in Ghalyun cafes. Other factors such as number of smokers, smoking rate, and weights of smoked tobacco may have significant effect on CO concentration; however, they have not been studied in the present work. This study provides further evidence and support Iran Health ministry's decision on banning Ghalyun smoking in public environments including cafes.

References

Ahmadi Asoor, A., Allahabadi, A., 2011. Measuring the Air Pollutants in Sabzevar, Iran. *Journal of Sabzevar University of Medical Sciences 18*, 140–147.

ATSDR (Agency for Toxic Substances and Disease Registry), 2009. Toxicological Profile for Carbon Monoxide. Atlanta, Georgia.

Baker, R.R., Proctor, C.J., 1990. The origins and properties of environmental tobacco–smoke. *Environment International* 16, 231–245.

Burnett, R.T., Dales, R.E., Brook, J.R., Raizenne, M.E., Krewski, D., 1997. Association between ambient carbon monoxide levels and hospitalizations for congestive heart failure in the elderly in 10 Canadian cities. *Epidemiology* 8, 162–167.

Chaloulakou, A., Mavroidis, I., 2002. Comparison of indoor and outdoor concentrations of CO at a public school. Evaluation of an indoor air quality model. *Atmospheric Environment* 36, 1769–1781.

Chaloulakou, A., Mavroidis, I., Duci, A., 2003. Indoor and outdoor carbon monoxide concentration relationships at different microenvironments in the Athens area. *Chemosphere* 52, 1007–1019.

Chaloulakou, A., Fili, N., Spyrellis, N., 2000. Occupational Exposure to CO Concentrations in Enclosed Garages: Estimation of Blood COHb Levels. Environmental Pollution, Proceedings of the 5th International Conference, August 28–September 1, Thessaloniki, Greece.

Chowdhury, Z., Campanella, L., Gray, C., Al Masud, A., Marter–Kenyon, J., Pennise, D., Charron, D., Zuzhang, X., 2013. Measurement and modeling of indoor air pollution in rural households with multiple stove interventions in Yunnan, China. *Atmospheric Environment* 67, 161–169.

Dehghanzadeh, R., Ansarian, K., Aslani, H., 2013. Concentrations of carbon monoxide in indoor and outdoor air of residential buildings. *Journal of Health 3*, 29–40.

Ding, Y.S., Trommel, J.S., Yan, X.Z.J., Ashley, D., Watson, C.H., 2005. Determination of 14 polycyclic aromatic hydrocarbons in mainstream smoke from domestic cigarettes. *Environmental Science & Technology* 39, 471–478.

Eissenberg, T., Shihadeh, A., 2009. Waterpipe tobacco and cigarette smoking direct comparison of toxicant exposure. *American Journal of Preventive Medicine* 37, 518–523.

Fromme, H., Dietrich, S., Heitmann, D., Dressel, H., Diemer, J., Schulz, T., Jorres, R.A., Berlin, K., Volkel, W., 2009. Indoor air contamination during a waterpipe (narghile) smoking session. *Food and Chemical Toxicology* 47, 1636–1641.

Ghasemkhani, M., Naseri, F., 2008. Comparison of indoor air quality in restaurant kitchens in Tehran with ambient air quality. *Iranian Journal of Environmental Health Science & Engineering* 5, 59–64.

ICARC (Islamic Parliament Research Center), 1997. Regulations for Prohibit Smoking and Offers of Cigarettes and Other Tobacco Products in Public Places 2014, http://rc.majlis.ir/en#&panel1–1, accessed in January 2014.

IEPO (Iran's Environmental Protection Organization), 2012. Clean Air Standard, Tehran, Iran, http://www.doe.ir, accessed in January 2014.

Jacob, P., Abu Raddaha, A.H., Dempsey, D., Havel, C., Peng, M., Yu, L., Benowitz, N.L., 2011. Nicotine, carbon monoxide, and carcinogen exposure after a single use of a water pipe. *Cancer Epidemiology Biomarkers & Prevention* 20, 2345–2353.

Jo, W.K., Lee, J.Y., 2006. Indoor and outdoor levels of respirable particulates (PM_{10}) and Carbon Monoxide (CO) in high–rise apartment buildings. *Atmospheric Environment* 40, 6067–6076.

Knishkowy, B., Amitai, Y., 2005. Water–pipe (narghile) smoking: An emerging health risk behavior. *Pediatrics* 116, E113–E119.

La Fauci, G., Weiser, G., Steiner, I.P., Shavit, I., 2012. Carbon monoxide poisoning in narghile (water pipe) tobacco smokers. *Canadian Journal of Emergency Medicine* 14, 57–59.

Langston, J.W., Widner, H., Brooks, D., 2010. Carbon monoxide poisoning. *Encyclopedia of Movement Disorders* 1, 187.

Lim, B., Lim, G., Seow, E., 2009. Case of carbon monoxide poisoning after smoking shisha. *International Journal of Emergency Medicine* 2, 121–122.

MHMEI (Ministry of Health and Medical Education), 2012. Occupational Exposure Limits, 3rd Edition, Environmental and Occupational Health Center, Tehran, Iran.

Naeher, L.P., Smith, K.R., Leaderer, B.P., Mage, D., Grajeda, R., 2000. Indoor and outdoor $PM_{2.5}$ and CO in high – and low–density Guatemalan villages. *Journal of Exposure Analysis and Environmental Epidemiology* 10, 544–551.

NIOSH (The National Institute for Occupational Safety and Health), 2012. Criteria for a Recommended Standard: Occupational Exposure to Carbon Monoxide, Atlanta.

OSHA (Occupational Safety and Health Administration), 2012. Carbon monoxide, U.S. Department of Labor, Washington, DC.

Padro–Martinez, L.T., Patton, A.P., Trull, J.B., Zamore, W., Brugge, D., Durant, J.L., 2012. Mobile monitoring of particle number concentration and other traffic–related air pollutants in a near–highway neighborhood over the course of a year. *Atmospheric Environment* 61, 253–264.

Rashidi, M., Massoudi, M.S., 1980. A study of the relationship of street level carbon monoxide concentrations to traffic parameters. *Atmospheric Environment 14*, 27–32.

Reboul, C., Thireau, J., Meyer, G., Andre, L., Obert, P., Cazorla, O., Richard, S., 2012. Carbon monoxide exposure in the urban environment: An insidious foe for the heart? *Respiratory Physiology & Neurobiology* 184, 204–212.

Repace, J.L., Lowrey, A.H., 1982. Tobacco Smoke, Ventilation, and Indoor Air Quality. *Ashrae Transactions* 88, 895–914.

Sajid, K.M., Akhter, M., Malik, G.Q., 1993. Carbon monoxide fractions in cigarette and hookah (hubble bubble) smoke. *JPMA–The Journal of the Pakistan Medical Association* 43, 179–182.

Satran, D., Henry, C.R., Adkinson, C., Nicholson, C.I., Bracha, Y., Henry, T.D., 2005. Cardiovascular manifestations of moderate to severe carbon monoxide poisoning. *Journal of the American College of Cardiology* 45, 1513–1516.

Turkmen, S., Eryigit, U., Sahin, A., Yeniocak, S., Turedi, S., 2011. Carbon monoxide poisoning associated with water pipe smoking. *Clinical Toxicology* 49, 697–698.

U.S. EPA (Environmental Protection Agency), 2013. Typical Indoor Air Pollutants, IAQ Reference Guide, Appendix E, accessed in October 2013.

Verma, D.K., 2000. Adjustment of occupational exposure limits for unusual work schedules. *American Industrial Hygiene Association Journal* 61, 367–374.

Weber, L.P., Al–Dissi, A., Marit, J.S., German, T.N., Terletski, S.D., 2011. Role of carbon monoxide in impaired endothelial function mediated by acute second–hand tobacco, incense, and candle smoke exposures. *Environmental Toxicology and Pharmacology* 31, 453–459.

WHO (World Health Organization), 2010. WHO Guidelines for Indoor Air Quality: Selected Pollutants, Geneva, Switzerland.

Zhong, K., Yang, F., Kang, Y.M., 2013. Indoor and outdoor relationships of CO concentrations in natural ventilating rooms in summer, Shanghai. *Building and Environment* 62, 69–76.