Environ Sci Pollut Res (2015) 22:7176–7182
DOI 10.1007/s11356-014-3947-8

RESEARCH ARTICLE

A pilot study of indoor air quality in screen golf courses

Sun-Ju Nam Goung · Jinho Yang · Yoon Shin Kim · Cheol Min Lee

Received: 15 October 2014 / Accepted: 17 November 2014 / Published online: 17 December 2014

Abstracts The aims of this study were to provide basic data for determining policies on air quality for multi-user facilities, including the legal enrollment of the indoor air quality regulation as designated by the Ministry of Environment, and to establish control plans. To this end, concentrations of ten pollutants (PM_{10}, carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NO_2), formaldehyde (HCHO), total volatile organic compounds (TVOCs), radon (Rn), oxone (O_3), total bacteria counts (TBC), and asbestos) in addition to nicotine, a smoking index material used to determine the impact of smoking on the air quality, were investigated in indoor game rooms and lobbies of 64 screen golf courses. The average concentration of none of the ten pollutants in the game rooms and lobbies of screen golf courses was found to exceed the limit set by the law. There were, however, pollutant concentrations exceeding limits in some screen golf courses, in order to establish a control plan for the indoor air quality of screen golf courses, a study on the emission sources of each pollutant was conducted. The major emission sources were found to be facility users' activities such as smoking and the use of combustion appliances, building materials, and finishing materials.

Keywords Screen golf courses · Indoor air quality · Multi-user facilities · Nicotine · Pilot study · Indoor public sports facilities

Introduction

The range of activities people perform has decreased into indoor spaces due to industrialization and urbanization. This transition into indoor space has increased the significance of indoor air quality to people. As indoor activity time increased, the amount of inhalation exposure to indoor air pollutions of low concentrations became larger than exposure to outdoor air pollutants of high concentration, thus emerging as a very important national health issue.

The Korea Ministry of Environment enacted the "Indoor Air Quality Regulation in Multi-user facilities" in 2003, since controlling indoor air quality in multi-user facilities help people to recognize its significance. This program was implemented in 17 multi-use facilities (subway station, underground shopping center, passenger terminal waiting room, airport terminal of airport facilities, waiting room of port facilities, library museum, art gallery, medical institution, indoor parking lot, train station waiting room, large scale shop, public childcare center, public elderly nursing home, charged elderly nursing home, special clinic for elderly, Sauna, postnatal care center, and funeral hall). Hereafter, the Korea Ministry of Environment publicly increased its control over various multi-user facilities in line with the growing recognition of public health and environment as well as indoor environment. Consequently, they established norms to be implemented by all types of multi-user facilities in 2012, such as indoor exhibition facilities, movie theaters, learning center, business facilities, and parlors for internet computer games. These actions were undertaken based on the research for the legal enrollment of environmental policies for multi-user facilities to control indoor air quality.

Responsible editor: Constantini Samara

S.-J. N. Goung · Y. S. Kim
Institute of Environmental and Industrial Medicine, Hanyang University, Seoul, South Korea

C. M. Lee (✉)
Department of Integrated Environmental Systems, Pyeongtaek University, Pyeongtaek, South Korea
e-mail: cheolmin@ptu.ac.kr

J. Yang
Department of Public Health Sciences, Korea University, Seoul, South Korea

Recently, the number of indoor screen golf courses has increased along with the increase of golf hobbyists. Consequently, the population using these facilities has also grown. According to the investigation by the National Statistical Office, there are 7139 indoor screen golf courses in Korea. Those in the capital areas comprise 50 % of this total as follows: Seoul (1473), Incheon (289), and Gyeonggi-do (1771). Moreover, screen golf courses belong to “Sports Facility for All,” specified in Article 6 Chapter 2 (Public Sports Facility) of the Installation and Utilization of Sports Facilities Act (enforcement: 07/18/2012), and belong to “Registered Sports Facility Business” according to Article 10 (Sports Facilities Classification and Types) Chapter 3 (Sport Facility Business). Hence, this study has defined the screen golf range as a place where the entrance is the only open space. In screen golf courses like this, indoor air quality is poorly maintained since pollutants are emitted by the users’ intensive indoor exercise and by hitting the floor or screen with balls. Therefore, this study proposes air quality levels and a control plan. This is performed through investigation of indoor screen golf courses, in order to provide basic data for deciding policies such as legal enrollment of indoor air quality regulation in multi-user facilities in Korea and to improve public health and environment.

Materials and methods

Study target and period

Korea’s environment changes depending on its four distinct seasons. However, screen golf courses, which are the target facilities of this study, are located inside buildings and maintain constant temperature and humidity throughout the four seasons. Thus, there will be no significant seasonal impact on indoor air quality. Accordingly, this study investigated the indoor air quality of 64 screen golf courses located in the capital area, from September to November 2013, without the distinction of seasons. The investigation included ten pollutants, which were the control targets for indoor air quality regulation: PM_{10}, formaldehyde (HCHO), total volatile organic compounds (TVOCs), asbestos, radon (Rn), carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NO_2), ozone (O_3), and total bacteria counts (TBC). In addition, nicotine, which is the smoking index material, was also included, in order to investigate indoor smoking. All target pollutants were measured at respiratory organ positions of 1.2~1.5-m height, in the middle of the rooms where screens were installed and people exercised.

Measuring and analytical methods

Samples of PM_{10} were collected at a flow rate of 5 L/min for more than 6 h using a Mini-volume Air Sampler (Model 4.1, Airmetrics Co., USA). A Membra-fil membrane filter from Corning Costa with a diameter of 47 mm and pore size of 0.2 μm was used as the collection medium. The filter was preserved using electronic desiccators after sampling, and their concentrations were calculated by dividing the weight difference before and after sampling by the flow rate during sampling.

An ozone scrubber (water, USA) cluttered with KI was connected to the front part of 2,4-DNPH cartridge (Supelco, USA) and was used to measure HCHO levels. Measurements were carried out two consecutive times at a flow rate of 0.5 L/min for 30 min, and an average value was set as the measured concentration. Aluminum foil was used to prevent cartridge exposure to sun light when measuring samples. The measured samples were packed into a container that was coated with aluminum and kept refrigerated below 4 °C until the solvent was extracted. A vacuum elution rack (Supelco, USA) device and a HPLC (Younglin, Korea) were used to extract the solvent and analyze the samples, respectively.

A stainless adsorption tube (1/4 in.×9 cm, PerkinElmer, UK) filled with more than 200 mg of Tenax-TA (60/80 mesh, Supelco, USA) was connected to a Mini-pump (MP-∑30, SIBATA, Japan) to measure TVOCs using the solid adsorption method. Subsequently, the sampling was performed at two consecutive times at a flow rate of 0.2 L/min for 30 min, and an average value was set as a measured concentration. The flow rate before and after sampling was measured using a digital flow meter (Alltech, USA) to calculate total absorption flow rate. At this point, the change of flow rate before and after the sampling was <5 %. Both edges of the adsorption tube were closed using storage caps after sampling. The adsorption tube was kept refrigerated below 4 °C and analyzed within a week. TurboMatrix ATD (PerkinElmer, UK) thermodesorber and gas chromatography (GC-MSD, HP-6890, Agilent 5973 Inert, USA) equipment were used for the analysis. In order to measure asbestos, an absorption pump was connected to a filter holder in which the membrane filter (pore size 0.8 μm, diameter 25 mm) was built. Sampling was then performed at a flow rate of 20 L/min for 1 h. After pretreatment, the sampled filter was analyzed using a phase-contrast microscope (CX42RF, OLYMPUS). To measure Rn, a consecutive monitoring equipment Rn1208 (Model 1027, Sun Nuclear Co. USA) was used.

A consecutive monitoring equipment, which uses a non-dispersive infrared analysis method, a chemiluminescent method, and an ultraviolet photometric method, was employed to measure CO/CO_2, NO_2, and O_3, respectively. Bacteria samples were collected using the Buck Bio Culture B30120 Pump Kit from Buck Bio-Culture™. The inside of the collector was antisepticised using 70 % of alcohol before the medium was installed and samples were collected. Trypticase Soy Agar (Lot 2087730, Becton Dickinson and Company, USA), to which 500 dL of cycloheximide was added, was used to suppress the growth of mycete. The medium, which completed sample collection, was transported to a microorganism analysis room immediately and was then cultured at 37 °C for 1 or 2 days in a culture medium. The concentration of bacteria was calculated by dividing the counted value of colonies formed on the medium after completing the culture by the volume of sampled air (m^3).

Nicotine was collected at a flow rate of 1 L/min for 3 h after connecting the XAD-4 sorbent tube (SKC Inc., USA) to a low flow rate pump (SHIBATA, Japan) at the sites for collecting indoor pollutants. The sampling tube was transported to an analytical room, and then ultrasonic extraction was carried out for 30 min using 1 mL of ethyl acetate, which contained 0.01 % of triethylamine. Hereafter, 1 μL of extracting solution was injected followed by analysis using the GC/NPD (HP6890, Agilent).

Results

The characteristics of the concentration distributions of pollutants in screen golf courses

The concentration of ten pollutants, which are controlled by the indoor air quality regulation in multi-user facilities enacted by the Korea Ministry of Environment, was investigated, by distinguishing game rooms and lobbies where people rest while awaiting games in screen golf courses. The investigation results are as follows (Table 1).

The average concentration of the ten pollutants investigated both in game rooms and lobbies of the screen golf courses did not exceed the respective standards. However, PM_{10} showed an exceedance rate of 9.8 % (the number of measured sites exceeding standards/the number of total measured sites, 12/122); six game rooms and six lobbies exceeded the standard concentration. In addition, CO showed a 1.6 % exceedance rate (2/128); one room and one lobby exceeded the standard concentration. Moreover, NO_2 showed a 4.8 % exceedance rate (6/126); three game rooms and three lobbies exceeded the standard concentration. Furthermore, HCHO showed an 8.0 % exceedance rate (9/112); six game rooms and three lobbies exceeded the standard concentration. Still, TVOCs showed a 7.3 % exceedance rate (9/124); four game rooms and five lobbies exceeded the standard concentration. While, TBC showed a 6.5 % exceedance rate (8/123), two game rooms and six lobbies exceeded the standard concentration. Finally, CO_2, O_3, TVOCs, asbestos, and Rn did not exceed the standard concentration at all measured sites.

Investigation of the main pollutants in game rooms and lobbies

Methods should be established to control the air quality in screen golf courses, through investigation of the pollutants in the game room and lobby. The main sources of pollutants need to be investigated. Hence, the concentration ratio of PM_{10} and CO_2 was 1.04±0.42 and 1.05±0.15, respectively (Table 2). These results indicate that even though the sources of PM_{10} and CO_2 existed at both places, the amount in the game rooms was higher than in the lobbies. Carbon dioxide in screen golf courses was produced mainly by people's breathing. The space of game rooms was smaller than the lobbies; therefore, CO_2 increased due to people's breathing during golf. The concentration ratio of CO, NO_2, and O_3 was 1.08±0.59, 0.02±0.02, and 0.005±0.005, respectively, which indicates that the source of CO emission more possibly existed in lobbies more than in game rooms. Laser printers in the counter of lobbies were the only emission source of O_3 in screen golf courses. The concentrations of HCHO, TVOCs, and bacteria were 1.35±0.82, 1.65±2.79, and 1.35±0.62, respectively, which indicated that their emission sources mainly existed in game rooms than in lobbies. No asbestos was detected, which indicated that there was no emission source in the game rooms and lobbies. The concentration of Rn was 1.07±0.45, which indicated that the concentration at game rooms was slightly higher than in the lobbies.

Nicotine concentration in screen golf courses

In Korea, most of the multi-user facilities have been designated as non-smoking facilities. However, screen golf courses have not yet been designated as non-smoking facilities; therefore, indoor smoking is permitted. Indoor smoking is the main source of irritating indoor air quality. Hence, nicotine concentration was investigated at game rooms and lobbies to determine the impact of indoor smoking in screen golf courses on the indoor air quality. The average concentration of nicotine in screen golf courses was 0.8±0.7 μg/m^3 (Table 3). The average concentrations at game rooms and lobbies were 0.9±0.7 and 0.6±0.6 μg/m^3, respectively, which indicate that there was a statistically meaningful difference between the two places. This difference indicated that people smoke more at game rooms than at lobbies.

Discussion

The Korea Ministry of Environment enacted indoor air quality regulation in multi-user facilities. Standards have been established for the ten pollutants in consideration of the facility user's health and have been enforced to control the indoor

Table 1 Pollutant concentration distribution in the air in screen golf courses

Pollutant	Site	*N* value	Mean	S.D.[a]	Min[b]	Max[c]	*p* value
PM_{10}	Game room	61	72.2	54.8	24.6	270.7	>0.05
(μg/m^3)	Lobby	61	70.6	53.1	22.5	289.8	
CO_2	Game room	64	615.9	115.8	320.0	934.6	<0.05
(ppm)	Lobby	64	575.6	112.2	336.3	885.3	
CO	Game room	64	3.1	3.1	0.6	21.7	>0.05
(ppm)	Lobby	64	2.9	2.4	0.5	12.9	
NO_2	Game room	64	0.03	0.01	0.03	0.06	>0.05
(ppm)	Lobby	64	0.03	0.01	0.03	0.06	
O_3	Game room	63	0.005	0.006	0.001	0.023	>0.05
(ppm)	Lobby	62	0.005	0.005	0.001	0.025	
HCHO	Game room	58	53.8	32.9	10.0	137.6	>0.05
(μg/m^3)	Lobby	54	45.5	28.9	10.7	123.0	
TVOCs	Game room	63	186.8	180.2	23.4	768.0	>0.05
(μg/m^3)	Lobby	61	179.2	174.6	17.6	798.9	
TBC	Game room	61	383.1	242.6	112.7	1520.0	>0.05
(CFU/m^3)	Lobby	62	358.4	281.6	70.1	1395.0	
Asbestos	Game room	61	0.002	0.001	0.001	0.005	>0.05
(fiber/cc)	Lobby	61	0.002	0.001	0.001	0.005	
Rn	Game room	57	17.3	8.4	7.4	40.7	>0.05
(Bq//m^3)	Lobby	57	18.6	10.1	7.4	48.1	

[a] Standard deviation; [b] Minimum concentration; [c] Maximum concentration

air quality of 21 groups of multi-user facilities. Screen golf courses are one of the multi-user facility groups that are used by many unspecified persons, but are not target facilities for the regulation on indoor air quality control. However, the number of indoor screen golf courses and golf lovers in Korean are growing, and thus the number of facilities and users of these facilities are growing. In addition, social concern and demand for these facilities to be enrolled as target facilities controlled by the indoor air quality regulation and control plans to be established have increased. Consequently, this study was carried out to investigate the indoor air quality in screen golf courses in Korea and to provide basic data in order to enroll those facilities as a target controlled by indoor air quality regulation in multi-user facilities, enacted by the Korea Ministry of Environment, as well as to establish control plans. This study is meaningful since it is the first study to investigate the indoor air quality in the indoor screen golf courses in Korea and abroad.

In this study, the average concentration of the ten target pollutants, which were investigated in game rooms and lobbies in 64 screen golf courses, did not exceed the standard for indoor air quality in multi-user facilities as designated by the Korea Ministry of Environment. This indicated that the air quality in screen golf courses was good. However, some screen golf courses exceeded the current standard and created the need to establish a control plan to improve and maintain the indoor air quality of screen golf courses.

The concentration of PM_{10} exceeded the current standard of 150 μg/m^3 at 12 of the 122 places investigated. The emission source of PM_{10} existed at both game rooms and lobbies, but the emission concentration at game rooms was higher than that at lobbies. The main emission sources of indoor PM_{10} include rescattering by human activity, smoking, and combustion product (Spengler and sexton 1983). The main source of PM_{10} could be the human activity and

Table 2 The concentration ratios of pollutants in game room versus lobby

Pollutant	*N* value	Mean	S.D.[a]	Min[b]	Max[c]
PM_{10}	64	1.04	0.42	0.40	2.73
CO_2	64	1.05	0.15	0.71	1.46
CO	64	1.08	0.59	0.35	3.64
NO_2	63	0.02	0.02	0.00	0.06
O_3	62	0.005	0.005	0.001	0.023
HCHO	51	1.35	0.82	0.36	4.34
TVOCs	61	1.65	2.79	0.14	19.89
TBC	61	1.35	0.62	0.28	3.17
Rn	53	1.07	0.45	0.50	2.33

[a] Standard deviation; [b] Minimum concentration; [c] Maximum concentration

Table 3 Nicotine concentration in the air of screen golf courses

	N value	Mean (μg/m^3)	S.D.	*p* value
Game room	64	0.9	0.7	<0.05
Lobby	64	0.6	0.6	
Total	128	0.8	0.7	

rescattering since the intense activities of users of screen golf courses take place in spaces narrower than other multi-user facilities. In addition, smoking in screen golf course is still allowed, which could be the main PM_{10} emission source in screen golf courses. Similarly, rescattering of dust by users' activity and smoking were the main sources of PM_{10} concentration in screen golf courses. Therefore, control plans should aim to reduce rescattering and prevent indoor smoking.

CO is a toxic odorless material (IEH 1996) generated by imperfect combustion, and its main indoor sources are water heaters, gas or coal heaters, gas stoves, smoking (Gold 1992; Sterling 1991), and outdoor vehicle exhaust gasses or their inflow into buildings through ventilation systems. Given the calculation results of CO and nicotine concentrations in game rooms and lobbies, smoking was the main cause of CO in screen golf courses. The main source of CO in game rooms could be smoking, since there were no combustion facilities in these rooms. Even though smoking was actually allowed in both game rooms and lobbies, the concentration at game rooms was higher because the volume of game rooms was smaller than lobbies. In addition, the concentration of CO exceeded the current standard of 10 ppm at two of the 128 places investigated, which indicates that CO does not need to be a main target pollutant in screen golf courses. However, there are many reports on the impact of exposure to CO on health (Howell et al. 1997; Longo 1997; Madany 1992), which indicate that a continuous control plan should be considered.

NO_2 is a pollutant produced by the combination of nitrogen and oxygen during high temperature-combustion activity (Maroni et al. 1995). Indoor NO_2 is emitted by smoking as well as gas appliances, Kerosene heaters, and wood burning stove and is related to the inflow from outdoor (Chan et al. 1990). In this study, the NO_2 concentration at six of the 126 places investigated exceeded the standard concentration of 0.05 ppm. It was found that some screen golf courses were providing simple food to users using combustion appliances such as simple gas stoves in lobbies, which might be related to the increase of NO_2 concentration in screen golf courses. NO_2 is an oxidizing agent, which stimulates mucous membranes, affects lung function negatively, and increases respiratory infections (Lambert 1997). In addition, it is transformed to gaseous nitrous acid (HONO) in the airway, which adversely affects health (Postlethwait and Bidani 1990). Therefore, there is a need to establish control plans to minimize combustion activities that are regarded as the source of NO_2 increase in screen golf courses.

HCHO is a colorless gas with a strong order, and its main sources are carpeting and building materials such as particleboard, medium-density fiberboard, plywood, resins, and adhesives (Hines et al. 1993). It has been reported that exposure to HCHO causes sneezing, coughing, minor eye and skin irritation, damage to the respiratory tract, and carcinogenic effects (Morgan 1997; Koeck et al. 1997; Bardana and Montanaro 1991). In this study, nine of the 112 places investigated exceeded the standard concentration of 100 μg/m^3. This together with PM_{10} indicates the largest number of the places exceeding the standard, compared to the total number of places investigated. Considering the impact of exposure to formaldehyde on health, active control is needed compared to other pollutants. In addition, the investigation in game rooms and lobbies revealed that the main sources of HCHO were in the game rooms. Since building and finishing materials are the main sources of increased HCHO concentration in indoor air, it is recommended to lead business owners towards constructing game rooms using eco-friendly building and finishing materials authorized by the Korea Ministry of Environment, which emit less HCHO.

The main sources of VOCs are consumer and commercial products, paints and associated supplies, adhesives, furnishings and clothing, building materials, combustion appliances, and potable water. Exposure to these materials cause various acute and chronic diseases such as stimulation to eyes and respiratory organs, breakdown of the central nervous system, asthma, and carcinogenicity (Burton 1997; Maroni et al. 1995; Hodgson et al. 1991). In this study, nine of the 124 places investigated exceeded the standard concentration of 500 μg/m^3, and the investigation of the concentration in game rooms and lobbies revealed that main sources were in the game rooms. Like HCHO, the main sources of VOCs are also building materials, artificial lawns in batter's boxes of game rooms, and friction with golf clubs. The concentration per volume at game rooms measured relatively higher because the volume of game rooms was smaller than the lobbies. Therefore, it is recommended to lead business owners towards constructing game rooms with eco-friendly building materials authorized by the Ministry of Environment, which emit less VOCs as well as lead them to use eco-friendly artificial lawns that emit less hazardous pollutants.

TBC exceeded the standard of 800 CFU/m^3 at eight of the 123 places investigated. Like PM_{10} and HCHO, TBC presence and growth too need a control plan since the number of places that exhibited an excess over the standard was high. The exposure to microorganism such as bacteria can cause atopic disease, infections, and diseases due to the toxicity of microorganism (Montanaro 1997). It has been reported that typical diseases are rhinitis asthma, humidifier fever, extrinsic allergic alveolitis, and atopic dermatitis (IEH 1996). TBC in indoor air are affected by the inflow of exterior air, related indoor thermal environment, and the concentration ratio of game rooms versus lobbies revealed that the main sources of TBC in screen golf courses were in game rooms rather than in lobbies. Therefore, it is recommended that fine dust and thermal environments in game rooms should be controlled in order to control TBC in screen golf courses.

The concentrations of CO_2, O_3, asbestos, and Rn were lower than the standard at all the places investigated and proved not to be a problem in screen golf courses. However, all the materials except CO_2 have high toxicity and can possibly cause hazardous impacts on health. Accordingly, control plans should be established for continuous control.

Conclusions

The Ministry of Environment recognized the significance of indoor air quality to public health and enacted regulation in 17 multi-user facilities in order to control indoor air quality, which has been enforced since 2003. To meet the growing public demand, the Ministry of Environment extended the scope of the regulation to 21 groups of facilities since 2011. Recently, the number of screen golf courses and their users has grown; therefore, the control of air quality in these facilities has become important, and the public demand for the legal enrolment of these facilities has increased. Consequently, this study investigated the indoor air quality in screen golf courses and proposed a control plan, to provide basic data for policy decisions such as legal enrollment of indoor air quality regulation in multi-user facilities in Korea as well as improve public health and environment in the future.

This study investigated ten legally controlled pollutants in indoor air at the game rooms and lobbies of 64 indoor screen golf courses, using measuring and analytical methods designated by the law, from September to November 2013. It also investigated nicotine, which is a smoking index material to determine the impact of smoking on the air quality in indoor in screen golf courses.

The average concentration of ten pollutants, which were investigated in the game room and lobbies of screen golf courses, did not exceed each pollutant standard set by the law. However, some screen golf courses exceeded the current standards. Hence, control plans are required to improve and control the air quality of indoor screen golf courses.

An investigation to determine the source of each pollutant was conducted to control indoor air quality in screen golf courses and establish plans to reduce the pollutants. The result revealed that PM_{10} was emitted by the rescattering of dusts due to users' activities and smoking, while CO was emitted mainly by smoking in screen golf courses. NO_2 was emitted mainly by gas combustion appliance used for user's convenience at lobbies, while mainly building materials, finishing materials, and artificial lawns at the golf batter's boxes in game rooms emitted HCHO and TVOCs.

Since bacteria are related to the concentration of dust, the main source should be especially prevented to control air quality in screen golf courses. In addition, indoor combustion activities should also be forbidden. Hereafter, active activities for reduction, such as construction using eco-friendly building materials and ventilation using air purifier and heating/air-conditioning equipment, should be considered.

Indoor screen golf courses are the indoor public sports facilities developed in modern society along with civilization, and the number of these facilities in Korea is increasing each year. The number of users is also increasing, so the demand for controlling indoor air quality of indoor screen golf courses is escalating. The result of this study revealed that the average concentration of pollutants did not exceed the standard for each pollutant. However, exceedances took place in some facilities; hence, continuous control is needed through the legal enrollment in the future. In addition, prior to the legal enrollment, the studies on setting the suitable and allowable standards should be conducted first, through a health risk assessment and in the consideration of the nature of indoor screen golf courses and the patterns of users. Based on the result of such studies, legalization should be carried out.

References

Bardana EJ, Montanaro A (1991) Formaldehyde: an analysis of its respiratory, cutaneous, and immunologic effects. Ann Allergy 66(6):441–452

Burton BT (1997) Volatile organic compounds. In: Bardana EJ, Montanaro A (eds) Indoor air pollution and health. Marcel Dekker, New York, pp 127–152

Chan CC, Yanagisawa Y, Spengler JD (1990) Personal and indoor/outdoor nitrogen dioxide exposure assessments of 23 homes in Taiwan. Toxicol Ind Health 6(1):173–182

Gold DR (1992) Asbestos exposure in buildings. Clin Chest Med 13(2): 231–242

Hines AL, Ghosh TK, Loyalka SK, Warder RC (eds) (1993) Indoor air-quality and control. Prentice-Hall, Englewood Cliffs

Hodgson MJ, Frohlinger J, Permiar E, Tidwell C, Traven ND, Olenchock SA, Karpf M (1991) Symptoms and micro-environmental measures in non-problem buildings. J OccupMed 33(4):527–533

Howell J, Keiffer MP, Berger LR (1997) Carbon monoxide hazards in rural Alaskan homes. Alaskan Med 39(1):8–11

IEH (Institute for Environment and Health) (1996) IEH assessment on indoor air quality in the home. Institute for Environment and Health. Leicester, UK

Koeck M, Pichler-Semmerlrock FP, Schlacher R (1997) Formaldehyde-study of indoor air pollution in Austria. Cent Eur J Public Health 5(3):127–130

Lambert WE (1997) Combustion pollution in indoor environments. In: Bardana EJ, Montanaro A (eds) Indoor air pollution and health. Marcel Dekker, New York, pp 83–103

Longo LD (1997) The biological effects of carbon monoxide on the pregnant woman, fetus, and new-born infant. Am J Obstet Gynaecol 129(1):69–103

Madany IM (1992) Carboxyhemoglobin levels in blood donors in Baharin. Sci Total Environ 116(1):53–58

Maroni M, Seifert B, Lindvall T (Eds) (1995) National and regional distributions of airborne radon concentrations in US homes. Health Phys 66(6):699–706

Montanaro A (1997) Indoor allergens: description and assessment of health risks. In: Bardana EJ, Montanaro A (eds) Indoor air pollution and health. Marcel Dekker, New York, pp 201–214

Morgan KT (1997) A brief review of formaldehyde carcinogenesis in relation to rat nasal pathology and human health risk assessment. Toxicol Pathol 25(3):291–307

Postlethwait EM, Bidani A (1990) Reactive uptake governs the pulmonary air space removal of inhales nitrogen dioxide. J Appl Physiol 68(2):594–603

Spengler JD, Sexton K (1983) Indoor air pollution: a public health perspective. Science 221(4605):9–17

Sterling TD (1991) Concentrations of nicotine, RSP, CO and CO2 in non-smoking areas of offices ventilated by air recirculated from smoking designated areas. Am Ind Hyg Assoc J 52(10): 564–565