Original Paper

Indoor Built Environment

Indoor Built Environ 1997;6:337–343

Accepted. July 4, 1997

M. del Rosario Alfaro

Laboratorio de Estudios en Contaminantes del Aire, Escuela de Ciencias Ambientales, Universidad Nacional, Heredia, Costa Rica

Characterisation of Indoor Air Quality in Large Urban Centres in Central America

Key Words
Central America
Respirable suspended particles
Nicotine
Carbon monoxide
Carbon dioxide

Abstract
Levels of gas and particle-phase substances present in the indoor air at non-industrial sites in Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama; including offices, hospitals and restaurants, were measured during 1993 and 1994. Samples collected at 40 sites were analysed for respirable suspended particles (RSP, $d_{50} < 3.5$ μm), ultraviolet RSP (UV-RSP) as a marker for environmental tobacco smoke, carbon monoxide, carbon dioxide, and nicotine. Levels of RSP were very high at several sites, varying within the ranges of 34–421 μg/m^3 in restaurants, 21–242 μg/m^3 in hospitals and 13–196 μg/m^3 in offices. Carbon monoxide levels were also high at several sites with peak concentrations reaching 29, 20, and 19 ppm, respectively, in an office, a hospital and a restaurant. Infiltration and penetration of outdoor pollutants into the indoor environment occurred at all sites studied.

Introduction

Sixteen percent of the 30 million population of Latin Central America (fig. 1) live in their respective capital cities. The populations of the capital cities studied included (in millions, 1990 census): Guatemala City, Guatemala (1,057.210); Managua, Nicaragua (682,111); San José, Costa Rica (214,464); San Salvador, El Salvador (979,683); Tegucigalpa, Honduras (608,000); Panama City, Panama (1,116.823). While deterioration of outdoor air quality in large urban centres due to vehicular emissions, street dust and assorted industrial sources has been widely documented in several developing countries, no systematic indoor air quality studies have been conducted in Central America to date. When compared with developed nations, awareness of the importance of air quality is much less widespread in Central America and other developing countries. Knowledge of the levels of indoor pollutants is important for both developed and developing countries because individuals typically spend, respectively, approximately 90 and 70% of their time indoors [1].

In many respects, buildings located in large urban areas, such as the Central American cities profiled in this study, provide an excellent laboratory for such studies, as they stand at the mid-point in the urbanisation and industrialisation processes which have occurred extensively in developed countries. This paper presents a pilot indoor air quality study carried out in several of the largest cities of Central America (fig. 1). The objective of this study was to acquire data on the levels of a variety of airborne substances in offices, hospitals and restaurants. Although no effort was made in this study to choose sites at random, the sites investigated constitute, nevertheless, a broad sample of offices, hospitals and restaurants.

KARGER
Fax + 41 61 306 12 34
E-Mail karger@karger.ch
www.karger com

1420–326X/97/0066–0337$15.00/0

This article is also accessible online at:
http://BioMedNet.com/karger

M. del Rosario Alfaro
Laboratorio de Estudios en Contaminantes del Aire
Escuela de Ciencias Ambientales, PO Box 86-3000
Universidad Nacional, Heredia (Costa Rica)
Tel. +506 277 3292, Fax +506 277 3696, E-Mail malfarog@irazu.una.ac.cr

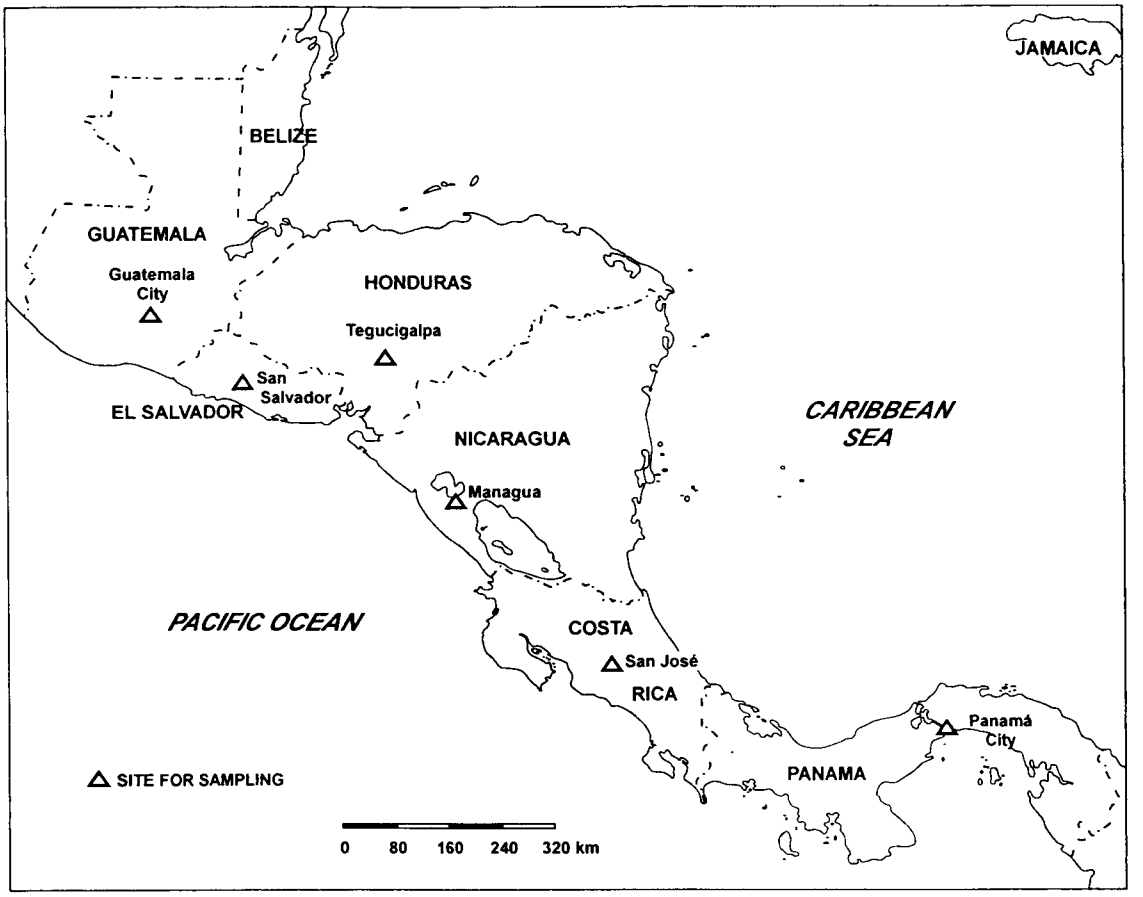

Fig. 1. Map of Central American countries and cities where the study was carried out.

Methods

Site Selection and Characteristics

A total of 39 sites were included in the study, including 14 office buildings, 11 hospitals and 14 restaurants, located in 6 cities from 6 countries (fig. 1). In order to minimise possible biasing effects of pollution from atypical buildings, roadways, and industrial pollution, we selected buildings types and sites which are common throughout Central America. The ventilation in the buildings included in this study relies mostly upon natural rather than mechanical units, distinguishing this from most other studies done in developed countries. The buildings ranged in height from a single story to either one or two additional stories. Smoking was allowed in some but not all of the buildings. Additional information on the location and site characteristics are shown in tables 1–3. Approval for monitoring at most sites was obtained from personnel having responsibility for building operations. While advanced notice was given before the actual samples were taken, it was accompanied by a note requesting that no special steps or measures be taken which might affect the levels at which the occupants are typically exposed. Sampling was conducted for a 2-hour period at each of the sampling sites.

Sampling Procedures

Prior to collection of samples, information was obtained and recorded on activity log sheets by a sampling team which registered the pattern and level of activity at each site. In preliminary visits, the sampling team identified, within each building, areas to which visitors were permitted free access, restricted access areas and areas with specially controlled climatic conditions – typically present because of the presence of sensitive office or other equipment. A mix of sampling sites was then chosen which reflected prevailing activity patterns. In offices and restaurants, the sampling equipment was placed near the centre of the room being studied. In hospitals, samples were taken in both emergency rooms and surgical areas. All office sampling was conducted during normal business hours. In the restaurants, samples were taken during the times of either lunch (12.00–14.00 h) or dinner (18.00–20.00 h). In the hospitals, sampling was carried out only when the sampling site was being used for its intended purpose. Other parameters annotated in the field log sheets included the number of people occupying the room, number of active smokers, and temperature.

Sample Analysis

Because the purpose of this study was to obtain air quality measurements unaffected by the sampling activity, the collection and measurement devices used were placed in a business briefcase

Table 1. Characteristics of the office sites in Central America – Costa Rica, Nicaragua, Honduras, El Salvador, Panama and Guatemala

Characteristics	CR-1	CR-2	CR-3	NIC-1	HON-1	HON-2	HON-3	SAL-1	SAL-2	PAN-1	PAN-2	PAN-3	GUA-1	GUA-2
Construction type	concrete-wood	concrete-wood	concrete-wood	cement	cement	concrete-wood	concrete-wood	concrete-wood	cement	concrete	cement-wood	cement	concrete	cement
Floor sampled	1st floor	3rd floor	1st and 2nd floor	1st floor	2nd floor	1st floor	1st floor	1st floor	1st floor	2nd floor	7th floor	1st floor	1st floor	2nd floor
Floor material	carpet	tile	tile	tile	tile	ceramic tile	ceramic tile	tile	tile	tile	tile	tile	tile-wood	cement
Ceiling material	concrete	concrete	concrete	concrete	particle board	particle board	wood	particle board	concrete	particle board	cement	particle board	wood	cement
Windows	4 closed 6 open	4 closed	4 closed	7 closed	10 closed	6 closed 1 open	3 open	2 open	2 open	1 open	1 closed	2 open 8 closed	11 closed	4 closed
Doors	1 closed 1 open	1 closed	1	3	2	2	2 open	2 open	1 closed	1 closed	1 closed	1 closed	1 closed	1 closed
Ventilation	natural	natural	natural	natural	fan	window unit	window unit	natural	natural	natural	fan	fan	natural	natural
Occupants	60	10	22	56	46	39	43	48	9	22	14	42	23	7
Activity level	high	medium	medium	high	high	high	high	high	medium	medium	low	high	high	medium
Smoking permitted	no	no	yes	yes	yes	yes	yes	yes	yes	no	no	yes	yes	no
Average smokers	0	1	0	0	8	6	8	1	0	0	0	0	4	0
Average temperature °C	27.5	25.5	25.5	21	28	22	26	28	29	25	25	24 7	29.5	29.5

equipped with sampling ports, through which known volumes of air were drawn. For the majority of analytes, the sampling time per site was 2 h. All pumps and gas analysers were calibrated prior to each field campaign. Details of the business briefcase (personal air sampling system, PASS) sampling unit and the methods used to determine the levels of the various analytes included in the study have been described elsewhere [2]. In brief, the methods of analysis were as follows:

Carbon Monoxide and Carbon Dioxide. The PASS briefcase was fitted out with an electrochemical CO monitor linked to an on-board data logger. Air was drawn in by a small pump to the face of the monitor. Carbon dioxide was measured using a Telaire electrochemical sensor.

Nicotine. Nicotine was collected by drawing air at 1 liter·min^{-1} through two glass tubes in series containing XAD-4 resin (SKS Inc.). After collection, the resin, front and rear, portions were extracted in ethyl acetate containing 0.01% triethylamine. Chromatographic separation involved the use of a Shimadzu GC-9A chromatograph (Shimadzu Corp.) equipped with a capillary column (SE-54, 15 m × 0.53 × 1.2 μm Econocap, (Alltech) and a NPD detector. The lower limit of detection was determined to be 0.05 μg·m^{-3} of nicotine. The procedure followed US EPA Report 600/4-90/010, Method IP-2A (1990).

Respirable Suspended Particles (RSP). RSP were measured gravimetrically using material collected by drawing air through a 3.5 μm cut-off cyclone onto a Teflon filter (Millipore, Type FA, size 1.0 mm). Pre- and post-weighing of the filters was carried out under conditions of standardised temperature and humidity and in the presence of radioactive sources to limit static electricity.

UV-RSP. After weighing the Teflon filters each was extracted with a known volume of methanol and quantified spectrophotometrically using 2,2′,4,4′-tetrahydroxybenzophenone as a surrogate standard. This procedure allows an upper-bound indication of environmental tobacco smoke (ETS) [2].

Results

Site Activities, Building Materials and Ventilation

The characteristics of the sites, including construction type, building floor sampled, building materials (floor and ceiling), number and disposition of doors and windows, ventilation system, number of occupants, activity level, and temperature are shown in table 1 (offices), table 2 (hospitals), and table 3 (restaurants). Sampling floor heights varied from street level (ground floor) to the 7th floor. In general, the level of smoking activity was greater in the restaurants; the highest numbers of smokers reported were 29 and 26, respectively, for smokers in a Honduras and an El Salvador restaurant. A wide variety of ceiling materials, including particle board, acoustic

Table 2. Characteristics of hospital sites in Central America – Costa Rica, Nicaragua, Honduras, El Salvador, Panama and Guatemala

Characteristics	CR-1	CR-2	CR-3	NIC-1	HON-1	HON-2	SAL-1	SAL-2	PAN-1	PAN-2	GUA-1
Construction type	cement	concrete	cement	concrete	cement	cement	cement	cement	cement	cement	cement
Floor sampled	1st floor	1st floor	1st floor	1st floor	2nd floor	1st floor	1st floor	1st floor	1st floor	1st floor	2nd floor
Floor material	ceramic	tile	tile	tile	ceramic	tile	tile	concrete	tile	tile	tile
Ceiling material	particle board	particle board	particle board	acoustical tile	particle board	particle board	concrete	asbestos	asbestos	asbestos	wood
Windows	none	1 closed	4 closed	none	3 closed	5 closed	6 closed	2 closed	none	none	2 open
Doors	1 open	1 open	1 open	4 open	2 open 2 closed	2 closed	2 open	1 open	1 open	2 open	1 open
Ventilation	natural	natural	natural	natural	window unit	natural	natural	natural	natural	natural	natural
Occupants	22	12	10	39	11	32	26	32	21	42	19
Activity level	high	high	high	medium	medium	high	high	high	high	high	high
Smoking permitted?	no	no	no	no	no	no	no	no	no	no	no
Average smokers	0	0	0	1	0	0	0	0	0	0	0
Average temperature, °C	25	25	28	21	20	26	30	28	25	24	20

Table 3. Characteristics of the restaurant sites in Central America – Costa Rica, Nicaragua, Honduras, El Salvador, Panama and Guatemala

Characteristics	CR-1	CR-2	CR-3	NIC-1	NIC-2	HON-1	HON-2	HON-3	SAL-1	SAL-2	PAN-1	PAN-2	GUA-1	GUA-2	GUA-3
Construction type	concrete	concrete	concrete	concrete-glass	concrete-wood	cement	cement	cement-wood	cement	cement	cement	cement	cement	cement-glass	cement-glass
Floor sampled	1st floor	1st floor	1st floor	1st floor	1st floor	2nd floor	1st floor	1st floor	2nd floor	1st floor	1st floor	1st floor	1st floor	2nd floor	1st floor
Floor material	ceramic	carpet	carpet	tile	tile	ceramic	cement	tile	tile	ceramic	tile	tile	tile	ceramic	ceramic board
cement	bamboo	particle board	wood	wood	particle board	particle board	particle board	cement	particle board	concrete	particle board				
Ceiling material	particle	board	particle	board	particle	4 closed	2 ajar	2 closed	2 closed	2 closed	none	1 closed	1 open	none	8 closed
Windows	2 open	1 closed	1 closed	4 closed	4 closed	1 closed	2 open	2 open	1 ajar	open	area	1 open	1 open	1 open	1 open
Doors	1 open	1 open	1 open	2 open	2 open	1 closed 2 open	2 open 1 ajar	open area	1 open	1 open	1 open	1 open	1 open	1 ajar	1 open
Ventilation	natural	fan	natural	fan	fan	window unit	natural	natural	window unit	window unit	fan	fan	fan	natural	window unit
Occupants	16	27	32	38	5	37	68	12	18	17	62	67	30	18	12
Activity level	medium	high	high	medium	low	high	high	low	medium	medium	high	high	high	high	medium
Smoking permitted	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no
Average smokers	4	1	3	0	0	9	29	0	0	26	5	11	2	9	0
Average temperature °C	25	27	26	27	19	20	20	nd	27	27	24	20	22	20	19

Table 4. Indoor concentrations of gas- and particle-phase pollutants in Central America

	RSP mg·m^{-3}	Nicotine mg·m^{-3}	UV-RSP mg·m^{-3}	CO ppm	CO_2 ppm
Office site					
CR1	85.9	<dl	<dl	10.4	1,000
CR2	155	0.5	2.9	18	400
CR3	114	nd	2.4	11	800
GUA1	196	1.9	<dl	1.5	1,532
GUA2	56	<dl	6	16	1,567
SAL1	24	<dl	<dl	29	761
SAL2	46	<dl	<dl	9	2,794
HON1	92.9	5	12	13	1,870
HON2	65	0.97	<dl	4.1	550
HON3	217	3.8	14	12	1,807
NIC1	91.9	0.77	12	12	856
PAN1	44	<dl	<dl	4	1,409
PAN2	13	<dl	<dl	1.8	1,309
PAN3	30	<dl	<dl	9.2	873
Hospital site					
CR1	50	<dl	<dl	11.1	800
CR2	85.9	9.7	<dl	12.5	900
CR3	42.7	<dl	<dl	10.3	2,000
GUA1	242	<dl	<dl	4	851
GUA2	na	<dl	<dl	na	na
SAL1	162	<dl	<dl	20	941
SAL2	98	<dl	<dl	2	1,029
HON1	30.2	<dl	<dl	4	404
HON2	80.1	<dl	<dl	6	606
HON3	na	<dl	<dl	na	na
NIC1	80	<dl	<dl	12	856
PAN1	21.1	<dl	<dl	1.5	970
PAN2	72	<dl	<dl	1.5	1,187
PAN3	na	<dl	<dl	na	na
Restaurant site					
CR1	72.4	0.81	3.5	4.8	800
CR2	70.4	<dl	<dl	15.5	1,500
CR3	203	0.6	6.8	4.8	400
GUA1	271	1.04	<dl	9	889
GUA2	113	2.94	<dl	3.5	802
GUA3	34	<dl	<dl	2	948
SAL1	56	<dl	<dl	2	801
SAL2	123	<dl	<dl	8	718
HON1	401	0.53	38	11	1,278
HON2	421	12	47	10	856
NIC1	403	0.53	42	19	1,248
NIC2	412	0.6	na	11	800
PAN1	203	<dl	13	12.5	1,802
PAN2	54.2	4	13	<1	1,490
PAN3	na	na	na	na	na

<dl = Below the detection limit; na = not available.

Pearson correlation coefficients (r): RSP vs. UV-RSP: offices = 0.2365; restaurants = 0.9194; nicotine vs. UV-RSP: offices = 0.6286; restaurants = 0.4568; number of occupants vs. CO: offices = −0.2841; hospitals = −0.2707; restaurants = −0.0416; nicotine vs. CO: offices = 0.0882; restaurants = −0.0371.

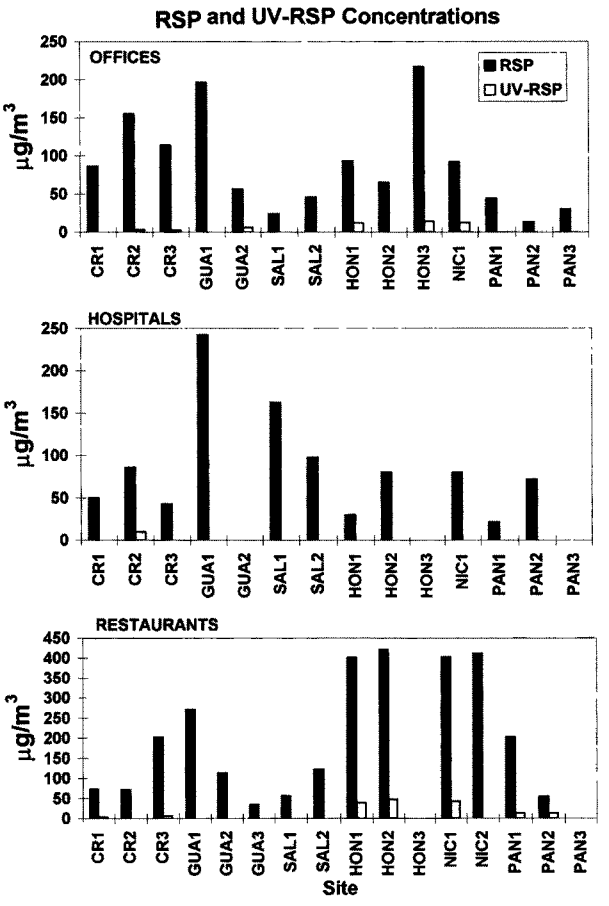

Fig. 2. Indoor concentrations of RSP and UV-RSP for all sites.

tiles, concrete, asbestos, wood, and (in one site) bamboo (tables 1–3), were used in the construction of the buildings. Floor materials included ceramic, tiles, concrete, carpets, cement, and wood (tables 1–3). During the sampling campaigns, temperatures varied between 19 and 30°C. The ventilation and air conditioning systems (HVAC) included window air conditioning units, electrical fans, and natural ventilation. Fuels used at the restaurants studied (table 3) included charcoal (Honduras, El Salvador, and Guatemala), electricity (Costa Rica, Guatemala, Nicaragua, El Salvador and Panama), and wood (Nicaragua only).

RSP, UV-RSP and Nicotine

Levels of RSP were very high at several sites, ranging from 34 to 421 µg·m^{-3} in restaurants, 21–242 µg·m^{-3} in hospitals and 13–196 µg·m^{-3} in offices (fig. 2 and table 4).

Peak RSP concentrations of 421 $\mu g \cdot m^{-3}$ and 412 $\mu g \cdot m^{-3}$, respectively, were found in a Honduras (charcoal) and a Nicaraguan (wood) restaurant (table 4). The lowest RSP levels were measured in a Panamanian office (13 $\mu g \cdot m^{-3}$) and hospital (21.1 $\mu g \cdot m^{-3}$), and a Guatemalan restaurant (34 $\mu g \cdot m^{-3}$).

Pearson correlations between RSP and UV-RSP were highest for the restaurants (0.9194) and lowest for the offices (0.2365).

The small number of smokers in most of the offices (0–8) was reflected in the nicotine and UV-RSP results, which ranged up to 3.8 and 14 $\mu g \cdot m^{-3}$, respectively (table 4). Correlations of nicotine with UV-RSP for the offices and restaurants were, respectively, 0.6286 and 0.4568. These low correlations reflect the infiltration of outdoor combustion products, as the windows and doors were left open or ajar most of the time.

CO and CO_2

Peak concentration levels of CO reached 29, 20, and 19 ppm, respectively, in an office, a hospital and a restaurant. The highest CO levels, respectively 29 and 20 ppm, were found at an office and a hospital located in El Salvador. Since there was little cooking activity in the hospital site, it is clear that infiltration from outdoors contributes to the observed CO levels at this site. Very low correlations were observed between CO and nicotine at all sites (table 4).

The lowest CO_2 levels (400 ppm) were found in Costa Rica, in an open restaurant and in an office with natural ventilation. The highest CO_2 level (2,794 ppm) was found in a Salvador office with natural ventilation and open windows. Considering that only 9 people were at this site during sampling, we conclude that this high CO_2 concentration came from outdoors. Another site with a very high CO_2 concentration (2,000 ppm) was a hospital in Costa Rica which had a large main door open to the hospital's parking facilities. In addition, the sampling location at this site was close to the kitchen facilities. The CO_2 concentration in a Panama restaurant (1,802 ppm) was also very high. Very low correlations were observed between CO_2 and the number of occupants in all sites (table 4), and indicate that the level of this component is also affected by cooking activities indoors and vehicular traffic outdoors.

Discussion

The results of this pilot study point to the importance of outdoor air as a contributor to the deterioration of air quality indoors. For example, since most of the sites studied had natural ventilation, it is reasonable to suggest that a large fraction of the various analytes measured at the various sites resulted from infiltration from the outdoors.

In the case of RSP, although our samples represent 2-hour averages, the peak RSP concentrations for several of the sites are clearly much higher than the 60 $\mu g \cdot m^{-3}$ (24 h average) WHO national ambient air quality standard for PM_{10}, and also higher than the recommended average RSP levels [4–7] for closed environments – which are that they should not exceed 100–150 $\mu g \cdot m^{-3}$. The results (table 4) show that, with few exceptions, at all sites (in all countries studied) RSP concentrations were very high compared with RSP levels found in US hospitals which have been reported [3] to range from 17 to 36 $\mu g \cdot m^{-3}$, respectively in non-smoking and smoking permitted areas: the levels found at the hospital sites in this study are alarmingly high.

The small number of smokers in most of the offices (0–8) was reflected in the nicotine and UV-RSP results. The nicotine values are well below the 50 $\mu g \cdot m^{-3}$ level recommended by ASHRAE [8]. Miguel et al. [9] have shown that methanol extracts of UV-RSP samples contain species which absorb strongly between 200 and 300 nm and which are probably polycyclic aromatic hydrocarbons. These compounds, which are the products of incomplete combustion, are found in tobacco smoke, both in the gas and particle phase and in smoke emitted from wood and gas stoves, in addition to local vehicular emissions [10, 11]. According to Miguel et al. [9] the UV-RSP method overestimates the contribution of ETS in urban sites, thus limiting the utility of UV-RSP as a marker for ETS in indoor environments. Consequently, we may conclude that the UV-RSP levels we measured in samples from all of the Central American sites may have resulted from a combination of ETS and combustion products resulting from cooking operations, vehicular and industrial emissions.

CO levels were high in about half of the sites (table 4). Although the results of the present study represent 2-hour sampling averages, the CO levels in half of the sites are much higher than the 9 ppm (8 h) WHO recommendation. In some buildings the influence of outdoor air had a negative impact on the indoor air quality. The office having the highest CO level, for example, was equipped with a stove for preparing or heating food. Because of the

extremely poor ventilation, much of the CO produced by the cooking or heating of food remained trapped in the office areas.

A similar picture was found with CO_2. A number of investigators have recommended that CO_2 levels not be permitted to exceed 800–1,000 ppm in occupied areas [6] but these levels were exceeded at some of our sites, a result almost certainly due to cooking activities indoors and vehicular traffic outdoors. Levels of CO_2 outdoors undoubtedly contributed to the levels of CO_2 found indoors in several of the sites.

Overall the results of this study reveal a number of significant indoor air quality deficiencies in offices, hospitals and restaurants, from which I draw the following conclusions.

The levels of both gas- and particle-phase substances found indoors are high for most sites studied compared to various international recommendations. At all sites this is due, to a greater or lesser extent, to infiltration and penetration of outdoor substances indoors. In particular the high levels of RSP found at several sites, particularly restaurants situated near heavily travelled streets, were influenced by vehicular emissions and the frying of foods. These factors, in addition, may have contributed to the high levels of UV-RSP observed.

Infiltration is not a factor in the case of nicotine, the levels of which were generally low although a nicotine value of 12 $\mu g \cdot m^{-3}$ was found in one restaurant. Most nicotine concentrations were lower than the 50 $\mu g \cdot m^{-3}$ level recommended by ASHRAE [8]. However, infiltration of outdoor combustion products probably accounts for the low correlations found between nicotine and UV-RSP in offices and restaurants, a finding which supports the work of others suggesting that UV-RSP is not a good tracer for ETS.

Where HVAC systems were in use, as expected, they were unable to reduce outdoor pollution. The practice of closing windows at some of the sites (to shield occupants from the effects of outdoor pollution and the traffic-generated noise) actually resulted in a build-up of pollution indoors. Also, overcrowding at some sites decreased thermal comfort by contributing to the elevated temperatures and adding to indoor levels of pollutants; particularly during times of peak activity in the offices.

Finally, I would conclude that efforts to improve indoor air quality in any large city, and especially in those in Central America, should first consider improvement of air quality outdoors, whether or not the buildings rely upon natural or mechanical ventilation. For the future, in Costa Rica, to further understand the relative importance of pollution sources, we are currently conducting simultaneous measurements of air pollutants both indoors and outdoors, to try and obtain a more quantitative picture of the effect of outdoor pollutants on indoor air quality.

Acknowledgements

The author wishes to express her gratitude to Clements Rupper (Universidad Nacional, Costa Rica) for nicotine analyses, student-assistants from the Universidad Nacional, Costa Rica, and to A.H. Miguel (University of California, Berkeley) for helpful discussions.

References

1 Smith QR: Assessing total exposure in developing-countries. Environment 1988;30:16–35.
2 Proctor CJ, Warren ND, Beavan MHG: Environ Technol Lett 1989;10:1003.
3 Miesner EA, Rudnick SN, Hu FC, Spengler JD, Preller L, Ozhaynak H, Nelson W: Particulate and nicotine sampling in public facilities and offices. J Air Pollut Control Assoc, 1989;39:1577–1582.
4 WHO: Air quality standards. Report of the WHO Commission on Health and Environment. Geneva, 1992.
5 Guerin M: The chemistry of environmental tobacco smoke: Composition and measurement. London, Lewis, 1992.
6 Robertson G: Indoor air quality guideline for Europe; in Lester JN, Perry R, Reynolds GL (eds): Quality of the Indoor Environment London, Selper, 1992.
7 Romiev I, Weitzenfeld H, Finkelman J: Urban pollution in Latin America and the Caribbean: Health Perspectives. World Health Stat Q 1990;43:153–166.
8 Turner S, Gross, RAJ: The measurement of environmental tobacco smoke in 585 office environments: A reply. Environ Int 1992;18:19–29.
9 Miguel AH, Aquino Neto FR, Cardoso JN, Vasconcellos PC, Pereira AS, Marquez KG: Characterization of indoor air quality in the cities of Sao Paulo and Rio de Janeiro, Brazil. Environ Sci Technol 1995;29:338–345.
10 Daisey JM, Miguel AH, Andrade JB, Pereira PAP, Tanner RL: An overview of the Rio de Janeiro aerosol characterization study. J Air Pollut Control Assoc 1987;37:15–23.
11 Offermann FJ, Loiselle SA, Daisey JM, Gundel LA, Hodgson AT: A pilot study to measure indoor concentrations of polycyclic aromatic compounds, Indoor Air '90, Proc 5th Int Conf Indoor Air Quality Climate; 1991, vol. 2, pp 379–384.