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Probabilistic Risk Assessment of Consumer Exposure to Particle-Bound PAHs at a Taiwanese Night Market

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ABSTRACT: The purpose of this study was to conduct a quantitative risk assessment for PAH exposure for consumers at a night market in Taiwan. The major methods assessed potential risk under different exposure scenarios based on BaP equivalent concentration (BaP_{eq}) and incremental lifetime cancer risk (ILCR) models. We performed experimental sampling at a night market from 27 October through 22 November 2011 in central Taiwan to analyze time-dependent particle-bound PAHs during open and closed hours. Our study revealed that the ratio of fine particle-bound PAH (<2 μm) concentration to total PAH concentration was nearly 40%; further, the ratio of PAH concentration (<10 μm) to total PAH concentration averaged 84%. This implicates fine particle-bound PAHs caused by cooking in night markets as a matter of health concern. We showed that BaP concentrations at the night market during open hours exceeded suggested permissible levels. Most importantly, we demonstrated that there are 89.05%, 99.62% and <50% probabilities of achieving ILCR levels greater than 10^{-6} for age groups corresponding to children, adults, and adolescents, respectively; yet, among these there was a zero percent probability of a risk greater than 10^{-4} (i.e., ILCR=10^{-4}). In contrast, when considering PAH exposure to workers, the cancer risk (95% confidence interval) was estimated at 3.8×10^{-5} (1.03×10^{-5}–1.34×10^{-4}). Our study suggests that the night market environment poses a potential health risk to its workers. These preliminary results can offer some important information to governments for understanding and controlling pollutants.

Key words: PAHs, Night markets, BaP, TEFs, Exposure

INTRODUCTION

Polycyclic aromatic hydrocarbons (PAHs) are a large group of organic contaminants that mainly result from pyrolytic processes and the incomplete combustion of organic matter at high temperatures. PAHs are persistent in the atmosphere. Most contributing sources consist of widespread emissions, such as cooking, incense burning, tobacco smoke (Castro *et al*., 2011), and traffic and industrial pollution (Liu *et al*., 2010; Ramirez *et al*., 2011). Evidence shows that some PAHs are considered strongly carcinogenic and are classified as priority pollutants by both the US Environmental Protection Agency (US EPA) and the European Environment Agency. Benzo[*a*]pyrene (BaP) is the most notably studied PAH because of its known carcinogenicity to humans (Group 1; see IARC 2013). Other PAHs, such as dibenzo[*a,h*]anthracene (DahA), have been classified as probably carcinogenic to humans (Group 2A). Naphthalene (NaP), benzo[*a*]anthracene (BaA), chrysene (Chr), benzo[*b*]fluoranthene (BbF), benzo[*k*]fluoranthene (BkF), and indeno[*1,2,3-cd*]pyrene (Ind) have been classified as possibly carcinogenic to humans (Group 2B). PAHs can be present in both gaseous and particulate phases depending upon their volatility (Ravindra *et al*. 2008; WHO-IPCS, 1998). The fact that PAH compounds possess different carcinogenicities and phases makes the risk estimation process for them complex.

In Taiwan, night markets are a unique cultural event and popular sightseeing spots for tourists; there are more than 300 throughout the country. Night markets can provide local delicacies, traditional snacks, entertainment and games. However, some air pollutants like PAHs are generated during food preparation and cooking processes such as roasting, grilling, barbecuing and smoking in outdoor cooking environments (SCF, 2002; See *et al*., 2006). When concentrations of such contaminants are high, the

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fumes can be variously harmful to both the cooks and the customers present at night markets. Zhao *et al*. (2010) investigated the air quality at night markets in southern Taiwan and found that CO_2, CO, and HCHO levels during open hours ranged from 433 to 916 ppm, 2.1 to 14.1 ppm, and 0.02 to 0.27 ppm, respectively. The PM_{10} and $PM_{2.5}$ values exceeded all recommended limits set by the Environmental Protection Administration Taiwan (EPAT) and are likely to cause adverse health effects (Zhao *et al*., 2010). As of now, many studies on PAHs involving pollution sampling and risk assessment have been conducted in Taiwan (Kuo *et al*., 2012; Chen and Chen, 2011; Liu *et al*., 2010; Chiang *et al*., 2009). However, few studies have focused on the impact of consumer exposure to PAHs on visitors. Zhao *et al*. (2011) estimated the potential human health risks posed by the inhalation of carcinogenic PAHs originating from combustion due to cooking at night markets. For PAH exposure among occupational workers, the excess lifetime cancer risk (ELCR) of cooks was found to be above the acceptable target risk range of 10^{-6} to 10^{-4}. The methodologies most employed for health risk assessments of human exposure to environmental PAHs have been toxic equivalence factors (TEFs), unit risks (URs), and incremental lifetime cancer risks (ILCRs). TEFs are calculated for various PAH mixtures, which are then ranked according to cancer potency relative to BaP. The method adopted from Nisbet and Lagoy (1992) is the most commonly cited: it generates the BaP equivalent concentration (BaP_{eq}) as a metric of cancer potency. The most used UR for PAHs established by the WHO (2000) is 8.7 cases per 100,000 people with chronic inhalational exposure to 1 ng/m^3 BaP over a lifetime of 70 years (UR = 8.7×10^{-5} m^3/ng). Several studies have used BaP_{eq} times this UR to estimate lifetime lung cancer risk (Ramirez *et al*., 2011; Castro *et al*., 2011; Wickramasinghe *et al*., 2011). On the other hand, many models for ILCR consider other exposure parameters such as body weight, exposure frequency, exposure duration, and contact rate for different exposure routes. Among these, the most important parameter is the oral cancer slope factor (CSF) of BaP (Brune *et al*., 1981; US EPA, 1991a, b, 2001; respective CSFs of 4.5, 5.9, 9.0, & 11.7, with a geometric mean of 7.3 per (mg/kg/d). Xia *et al*. (2010) and Wang *et al*. (2011) also used this method for risk assessment.

Hence, the objective of the present study was to estimate the consumer exposure to particle-bound PAHs at a representative night market in Taiwan. Specifically, our aims were (1) to conduct experimental sampling in order to analyze time-dependent particle-bound PAH concentrations across open and closed hours, and (2) to assess five different exposure scenarios by employing a quantitative risk assessment method for PAHs based on BaP_{eq} and ILCR models.

MATERIALS & METHODS

This study measured the concentrations of particle-bound PAHs in the Wenxin night market located at the intersection of Wenxin S. Rd. and Wenxin S. 5th Rd in central Taiwan from 27 October through 22 November, 2011. Fig. 1 shows the night market and the relative positions of the main street, gas station and parking areas. During the sampling period, the number of visitors reached nearly 334 per hour for weekends and 157 per hour for weekdays. There were 193 vendors in the Wenxin night market. Table 1 shows the cooking methods and fuel types used at the night market: grilling and deep-frying accounted for 60% of all cooking methods, and liquid petroleum gas accounted for 76% of all used fuel. During the sampling period, the temperature and relative humidity ranged from 28–36°C and 54–60%, respectively.

Sampling location were classified as consisting of two parts: the eating area which represented an area where people ate dinner, and the entertainment area which represented an area where people went shopping or took walks after dinner (Fig. 1). We assumed that customers spent 40 minutes and 20 minutes in the eating and entertainment areas, respectively. Hence, time-dependent particle-bound PAH concentrations were collected for one hour per day, from 19:00 to 20:00. Three kinds of sampling periods were defined: open hours on a weekday (Tuesday, Wednesday), open hours on a weekend (Friday, Saturday, Sunday), and closed hours (Monday, Thursday). Real-time particle-bound PAHs were detected by a particle-bound PAH detection device (Model #130). Additionally, a PAH sensor was incorporated into a 15-channel dust monitor (Grimm 1.108, Germany). The Grimm 1.108 measured particles by size, separating them into bins from 0.3 to 20 μm as: 0.3–0.4, 0.4–0.5, 0.5–0.65, 0.65–0.8, 0.8–1, 1–1.6, 1.6–2, 2–3, 3–4, 4–5, 5–7.5, 7.5–10, 10–15, 15–20, and >20 μm. The sampling flow rate was 1.2 L/min and the sampling height was 1.5 m for the eating and entertainment areas. The PAH sensor uses an excimer lamp to photo-electrically charge particulate matter which was then collected on a filter. There, an electrometer measures the resulting charge flow to give a relative measure of the particle-bound PAH concentration. Accurate measures of PAHs are possible with appropriate calibration. This PAH sensor can provide a qualitative measure of total PAH concentration more rapidly and cost-effectively than traditional methods; however, it cannot provide concentrations for individual PAH compounds. In order to estimate the concentrations of individual PAHs, we adopted the relative fractions of concentrations of individual PAHs to concentrations of total particle-

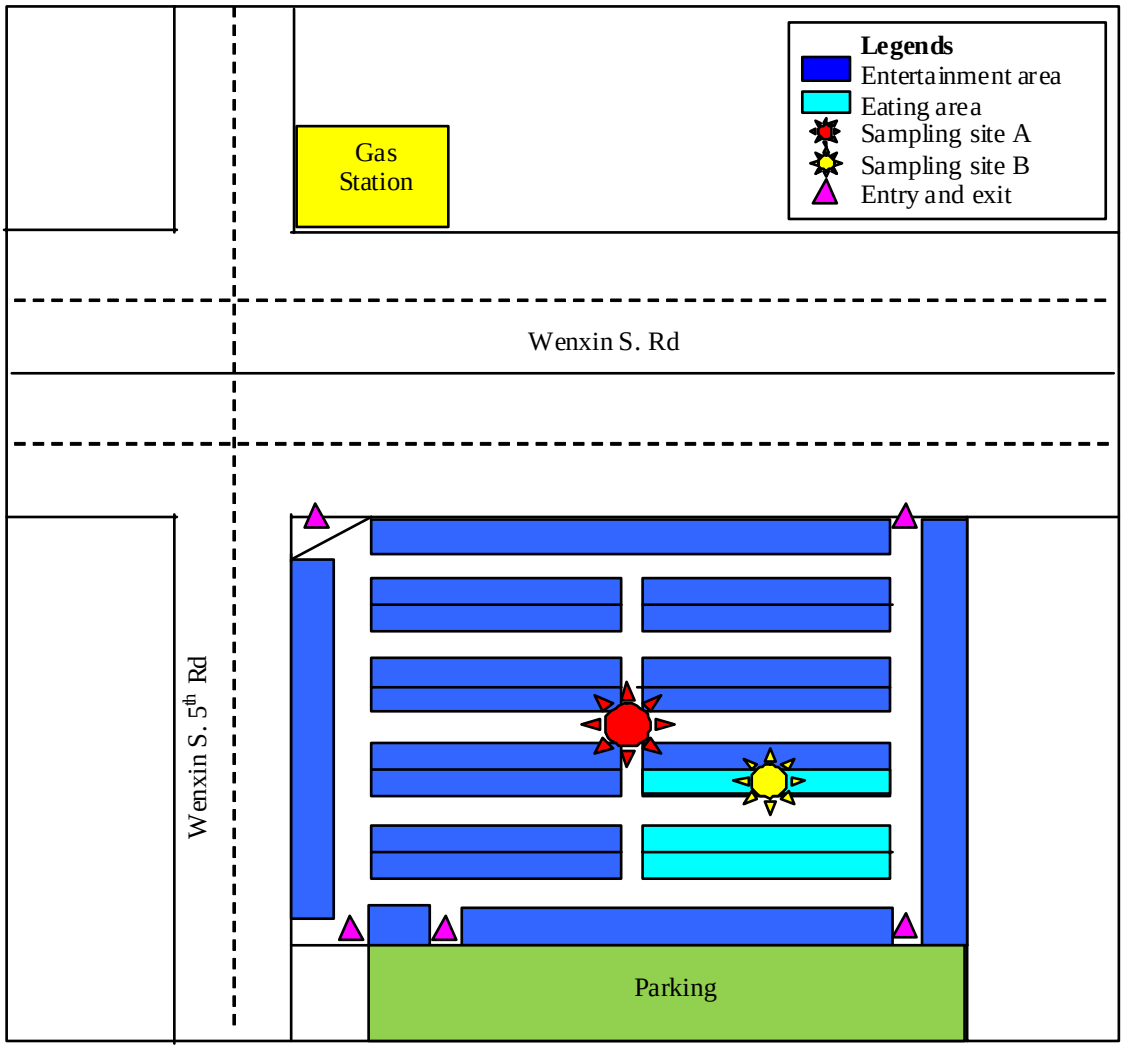

Fig. 1. The sampling site and relative positions of the main street, gas station and parking areas. Detailed legends were explained in text

Table 1. The way of cooking and fuel used in the night market

Way of cooking [a]	Vendor	Percentage (%)	Cooking fuel [b]	Vendor	Percentage (%)
Grill	20	33.33	Liquid petroleum gas	42	76.36
Deep-fry	16	26.67	Charcoal	12	21.82
Pan-fry	6	10.00	Alcohol gel	1	1.82
Cook	9	15.00			
Stir-fry	3	5.00			
Gravy	3	5.00			
Steam	3	5.00			
Total	60	100		55	100

[a] There were 176 vendors in the night market, and vendors which do not need cooking were excluded, such as fruit stands or bread stalls.

[b] The number of vendors using cooking fuel were 55; one kind of food may have one or more ways of cooking concurrently.

bound PAHs described by Zhao *et al*. (2011), who identified 16 gaseous and particulate PAHs at a night market from August to November 2009. The species they identified were naphthalene (Nap), acenaphthylene (AcPy), acenapthene (Acp), fluorine (Flu), phenanthrene (PA), anthracene (Ant), fluoranthene (FL), pyrene (Pyr), benzo[*a*]anthracene (BaA), chrysene (CHR), benzo[*a*]fluoranthene (BaF), benzo[*k*]fluoranthene (BkF), benzo[a]pyrene (BaP), dibenzo[*a,h*]anthracene (DBA), benzo[*g,h,i*]perylene (BghiP), and indeno[1,2,3,-*c,d*]pyrene (IND).

The concept of toxic equivalency factors (TEFs; WHO, 1998), which estimate carcinogenicity relative to benzo[*a*]pyrene, were used to assess the risks associated with consumer exposure to PAHs. We calculated each BaP equivalent (BaP_{eq}) by multiplying each PAH concentration with its corresponding TEF during weekdays and weekends as follows:

$$\mathrm{Bap}_{\mathrm{eq}i,j} = \left(\frac{2}{3}C_{1,i} + \frac{1}{3}C_{2,i}\right) \times F_j \times TEF_j \qquad (1)$$

where $C_{1,i}$ and $C_{2,i}$ represent the mean PAH concentration in the eating (C_1, μg/m^3) and entertainment areas (C_2, μg/m^3) on weekdays (i = 1) and weekends (i = 2), respectively. F_j expresses the fraction of each individual particle-bound PAH to total PAHs (Zhao *et al*., 2011). TEF_j expresses the TEF for each individual PAH *j (j = 1–16).*

Our probabilistic risk model integrated BaP_{eq} values and the incremental lifetime cancer risk (ILCR) approach to quantitatively estimate PAH exposure risk for three age groups: Child (0–11 years old), Adolescent (12–17 years old), and Adult (18–70 years old). We also explored five scenarios with varying exposure frequencies: Scenario 1, with two weekend visits per week; Scenario 2, with one weekday and one weekend visit per week; Scenario 3, with two weekday visits per week; Scenario 4, with one weekend visit per week; and Scenario 5, with one weekday visit per week.
The ILCR model for human inhalation was defined as:

$$R = \frac{Bap_{eq} \times CSF_i \times IR \times EF \times ED}{AT \times BW} \qquad (2)$$

where R is the incremental individual lifetime cancer risk by inhalation route, BaP_{eq} is the daily exposure level for Scenarios 1–5, CSF_i is the inhalation cancer slope factor (mg/kg/d)$^{-1}$, IR is the inhalation rate (m^3/d), EF is the exposure frequency (d/yr), ED is the exposure duration (yr), AT is the averaging time for carcinogenic effects (d), and BW is the body weight (kg). We treated CSF_i, EF, and BW in Eq. (2) probabilistically. Collins *et al*. (1991) estimated the cancer slope factor for BaP inhalation exposure based on three different inhalation rates in hamsters of 0.037, 0.063, and 0.158 m^3/d, which yielded CSF values of 6.1, 3.8, and 1.3 (mg/kg/d)$^{-1}$, respectively. The estimated methods used the linearized multistage model and limited animal data to estimate the human cancer potency of BaP. The linearized multistage model is based on several assumptions about carcinogenesis. (1) Cancer is assumed to be an irreversible process which originates in single cells and involves a number of biological events or stages. (2) The rate of occurrence of each stage varies linearly with dose, and (3) in addition the incidences of background and chemically induced cancer are assumed to be additive. Thus, in our study, we averaged those three CSF values and log-transformed appropriately to a log-normal distribution with a geometric mean of 3.14 (mg/kg/d)$^{-1}$ and a geometric standard deviation of 1.80. We used the Monte Carlo simulation methods to quantify the uncertainty of CSF values.

RESULTS & DISCUSSION

Fig. 2A shows the time-dependent total particle-bound PAH concentrations (μg/m^3) over the sampling period of 7:00 A.M. to 8:00 A.M. Results show that open hours (Tuesday, Wednesday, Friday, Saturday, Sunday) exhibited larger variations in concentration than closed hours (Monday, Thursday). Incremental PAH concentrations in the entertainment area were significantly lower than those in the eating area (Fig. 2B and 2C). Concentrations were 103.61±44.65 and 136.38±77.34 μg/m^3 in the entertainment area during weekdays and weekends, respectively (Fig. 2B) versus concentrations of 207.51±83.46 and 267.13±73.31 μg/m^3 in the eating area during weekdays and weekends, respectively (Fig. 2C). The results of our particle size analysis are shown in Fig. 2D. Size measurements of particles from 0.3 to 20 μm were collected and separated into bins of <2, 2–10, and 10–20 μm for both weekdays and weekends. Particle concentrations by bin were observed in the following descending order: 2–10 μm (43%), <2 μm (39–42%), and 10–20 μm (15–18%). The particle size distribution determines the inhalation risk of human exposure to hazardous air pollutants. Our study revealed the fraction of fine particle-bound PAHs (<2 μm) to total PAHs to be nearly 40%; further, the fraction of PAHs measuring <10 μm to total PAHs averaged 84%. Size differences between weekdays and weekends were not significant. Furthermore, we also analyzed particle size distribution by sampling location. Results showed particle concentrations in descending

order of 2–10 µm (46%), <2 µm (39%), and 10–20 µm (15%) in the eating area and <2 µm (38%), 2–10 µm (36%), and 10–20 µm (26%) in the entertainment area. These findings implicate fine particle-bound PAHs caused by cooking in the Wenxin night markets as a matter of health concern. Table 2 presents the estimated mean particle-bound concentrations for 16 PAH species and corresponding BaP_{eq} (µg/m^3) on weekdays and weekends. The individual-PAH fractions were adapted from Zhao *et al*. (2011) because our equipment could only monitor total particle-bound PAH concentrations. Based on these fractions, the PAHs of BaF and Ind contributed the most. In terms of Eq. (1), $C_{1,1}$ and $C_{1,2}$, the respective mean particle-bound PAH concentrations in the eating and entertainment areas on weekdays were 207.51 and 267.13 ìg/m^3; $C_{2,1}$ and $C_{2,2}$, corresponding values on weekends were 103.61 and 136.38 µg/m^3. Therefore, the BaP_{eq} exposures were 27.08 and 35.01 µg/m^3 on weekdays and weekends, respectively.

BaP_{eq} uses a reference compound to permit more accurate risk assessments concerning PAH exposure (Jung *et al*., 2010). Many research and government organizations have established permissible and recommended upper-limit values for exposure to BaP concentrations. In one case, Slooff *et al*. (1989) suggested the maximum permissible exposure level for ambient air was 1 ng/m^3 for BaP. In another, Ballesta *et al*. (1999) provided the target annual mean values of 1.3–7.0 ng/m^3 for BaP established by a few European countries. The WHO risk estimate for PAHs in air was originally based on lung cancer rates in coke oven workers, and has led to a health-based guideline value of 0.1 ng/m^3 BaP for ambient air (Bostrom *et al*., 2002). Our results reveal that BaP concentrations during both weekends (12.62 µg/m^3) and weekdays (9.76 µg/m^3) exceeded these suggested permissible levels (Table 2). Table 3 shows the input parameters, units, and estimations for consumers for our estimations of

Table 2. Estimated particle-bound PAHs concentrations and BaP_{eq} in weekday and weekend based on the fraction of compounds and toxic equivalency factors (TEF)

Compounds	Fraction (%) [a]	Mean Particle-bound PAHs (µg/m^3) [b]		TEFs [c]	BaP_{eq} (µg/m^3) [d]	
		weekday	weekend		weekday	weekend
Nap	0.54%	0.93	1.21	0.001	0.001	0.001
Acy	0.41%	0.72	0.93	0.001	0.001	0.001
Ace	0.84%	1.46	1.89	0.001	0.001	0.002
Flu	0.96%	1.66	2.15	0.001	0.002	0.002
Phe	2.19%	3.78	4.89	0.001	0.004	0.005
Anth	0.61%	1.06	1.37	0.01	0.011	0.014
FLt	4.26%	7.36	9.52	0.001	0.007	0.010
Pyr	6.27%	10.84	14.02	0.001	0.011	0.014
BaA	15.95%	27.57	35.65	0.1	2.757	3.565
Chr	7.47%	12.91	16.70	0.01	0.129	0.167
BaF	21.64%	37.41	48.37	0.1	3.741	4.837
BkF	8.06%	13.94	18.02	0.1	1.394	1.802
Bap	5.65%	9.76	12.62	1	9.760	12.621
DBahA	3.32%	5.74	7.42	1	5.741	7.424
BghiP	1.65%	2.85	3.68	0.01	0.028	0.037
Ind	20.18%	34.89	45.11	0.1	3.489	4.511
Total	**100%**	**172.88**	**223.55**		**27.08**	**35.01**

[a] We adopted the fraction of each individual particle-bound PAH to total PAHs (Zhao *et al*., 2011).
[b] The mean particle-bound PAHs concentration during sampling time (from 7:00 A.M. to 8:00 A.M). The concentration of 16 PAHs compounds was estimated by incremental particle-bound PAHs concentration times the fraction for individual PAHs. Incremental concentration expressed the original concentration in open hours minus those in closed hours. The reason is to decrease the background pollution sources such as the traffic sources.
[c] Estimated based on Nisbet and LaGoy (1992).
[d] BaP_{eq} (**µg/m^3**) were estimated by Eq. (1).

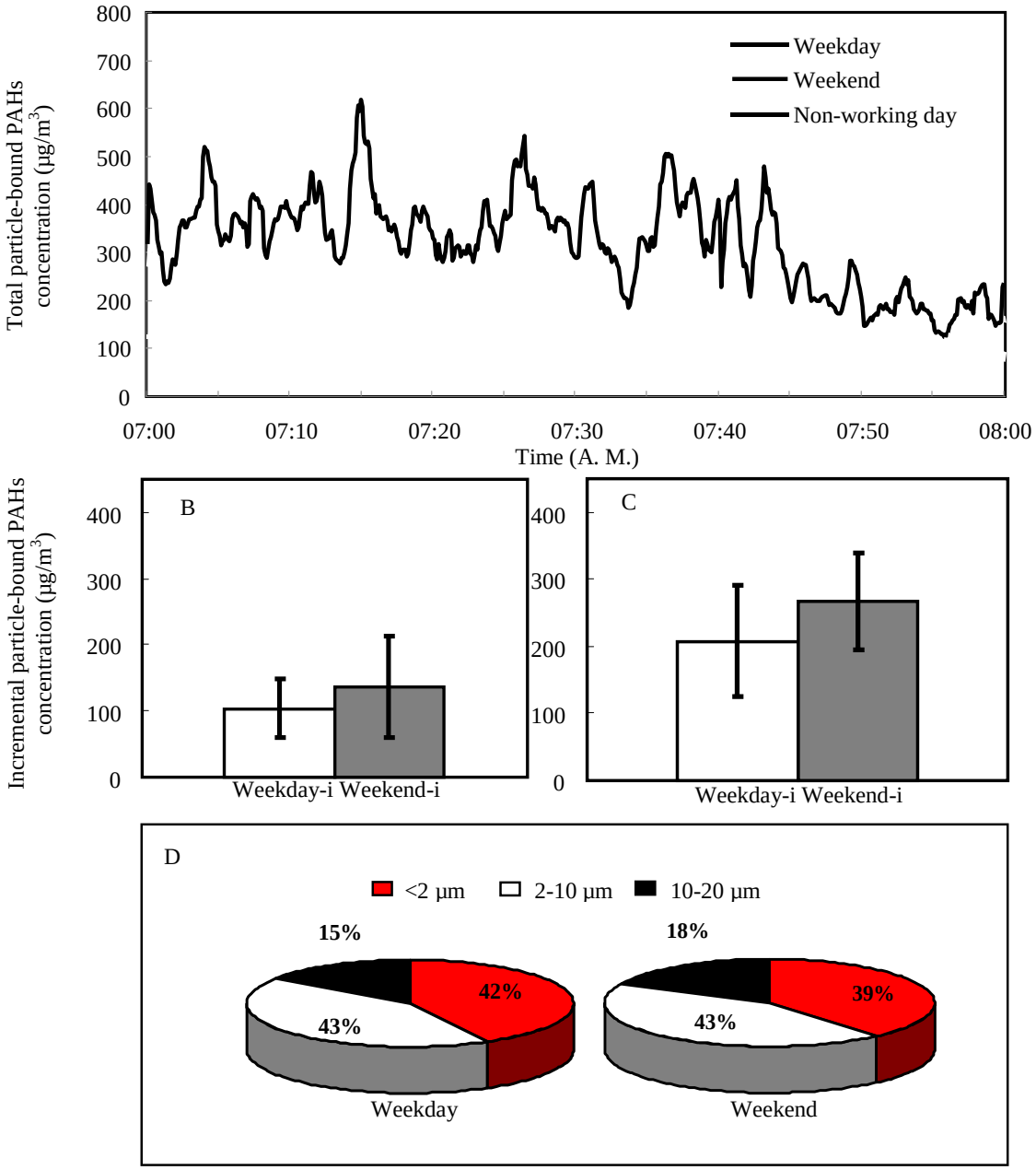

Fig. 2. (A) Time-dependent total particle-bound PAHs concentrations over the sampling period of 7:00 A.M. to 8:00 A.M. The dotted line divided the different sampling positions for eating area (7:00 A.M. to 7:40 A.M.) and entertainment area (7:40 A.M. to 8:00 A.M.). Incremental particle-bound PAH concentrations were shown in the entertainment area (B) and in the eating area (C). It was defined as the concentration in open hours minus those in closed hours. (D) Size distribution of particle-bound PAHs for all sampling duration (7:00 A.M. to 8:00 A.M.) in weekend and weekday

inhalation lifetime cancer risk caused by exposure to particle-bound PAHs at the Wenxin night market in Taiwan. We assumed the averaging time of 365 d/yr for 70 yrs (i.e., AT = 25,550 d). Table 4 shows the resulting predictions for the 2.5th, 25th, 50th, 75th, and 97.5th percentile values of BaP_{eq} concentrations for Scenarios 1–5. Scenario 1, in which there were two visits per week, yielded the highest exposure dose of BaP_{eq}. The mean estimated concentration with 95% confidence interval (CI) for BaP_{eq} was 68.05 μg/m^3 (43.31–108.38 μg/m^3). To compare the exposure risks between workers and consumers in the Wenxin night markets, we further

Table 3. Inhalation risk parameters considered as random variables (lognormal distribution with geometric mean and geometric stand deviation: LN (gm, gsd)) for different age groups consumers

Parameter definition	Units	Values[c]		
		Children	Adolescent	Adults
Age	yr	0-11	12-17	18-70
Body weight (BW)[a]	kg	LN(22.36, 1.15)	LN(32.41, 1.08)	LN(59.78, 1.07)
Inhalation rate (IR)[b]	m^3/d	LN(7.71, 1.27)	LN(7.71, 1.27)	LN(9.01, 1.26)
Exposure duration (ED)	yr	11	6	53
Averaging time (AT)	d	25550	25550	25550
Cancer slope factor (CSF)	mg/kg/d	LN(3.14, 1.8)	LN(3.14, 1.8)	LN(3.14, 1.8)

[a] Adapted from Department of Health, ROC (http://www.doh.gov.tw/cht/index.aspx#).
[b] Adapted from ICRP 66 (ICRP, 1994).
[c] LN means lognormal distribution with geometric mean (gm) and geometric standard deviation (gsd).

Table 4. Probabilistic carcinogenic potential of BaP_{eq} concentration (μg/m^3) for Scenario 1–5

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	BaP_{eq} concentration (μg/m^3)				
2.5%	43.31	41.59	28.24	21.65	14.12
25%	57.32	52.96	41.27	28.66	20.63
50%	68.05	60.91	51.23	34.02	25.61
75%	79.77	68.99	63.09	39.89	31.54
97.5%	108.38	88.78	98.08	54.19	49.04

estimated the ILCR for workers based on the following input parameters. EF, ED, and AT were assumed to be 260 d/yr (i.e., working five days per week per year), 53 yr, and 25,550 d, respectively. BW, IR, and CSF corresponded to the log-normal distributions (LN; with geometric means and geometric standard deviations (GM, GSD)) of LN(59.78, 1.07), LN(9.01, 1.26) and LN(3.14, 1.8), respectively. Results indicated that the mean concentration (95% CI) for BaP_{eq} was 156 μg/m^3 (106–315 μg/m^3). In conclusion, the exposure risks for workers were 2.3 times higher than for consumers.

Fig. 3 shows the frequency distributions of inhalation lifetime cancer risk for our three age groups according to Monte Carlo simulation methods. The dashed line expresses the acceptable risk: a literal one-in-a-million chance of additional human cancer over a 70-year lifetime (ILCR=10^{-6}). Results indicated that 89.05–11.39% of probabilities were greater than 10^{-6} for the Child group for exposure Scenarios 1–5 (A1–A5), while 99.62–62.10% were greater than 10^{-6} for the Adult group for exposure Scenarios 1–5 (C1–C5). However, for the Adolescent group, less than 50% of probabilities were greater than 10^{-6}. Under most regulatory programs, an ILCR between 10^{-6} and 10^{-4} indicates a potential risk, whereas an ILCR>10^{-4} indicates a high potential health risk (Liao and Chiang, 2006). Our results indicated that there was a zero percent probability of observing a risk greater than 10^{-4}, despite high probabilities of consumers encountering risks greater than 10^{-6}. In contrast, when considering exposure for workers, the cancer risk (95% CI) was estimated to be 3.8×10^{-5} (1.03×10^{-5}–1.34×10^{-4}), implying that PAH levels pose a potential risk to workers.

The major limitation of this study was the lack of personal inhaled concentrations and exposure frequency of consumers. Exposure measurement is the first step in risk assessment. However, it usually cost much in epidemiology surveys. Hence, we only assumed the one or two days visit per week as the baseline for estimating the potential inhalation risk. A questionnaire survey could be used to investigate and characterize the visiting frequency in the future. On the other hand, our study suggests that personal monitors may be more helpful in quantifying consumer exposure than environmental sampling. Secondly, BaP is the most studied carcinogenic PAH and one of the most potent and is often used as a toxicological prototype or surrogate for all carcinogenic PAHs. However, the specific CSF study data for different age groups were limited. For animal inhalation experiment, Collins *et al*. (1991) summarized the most important

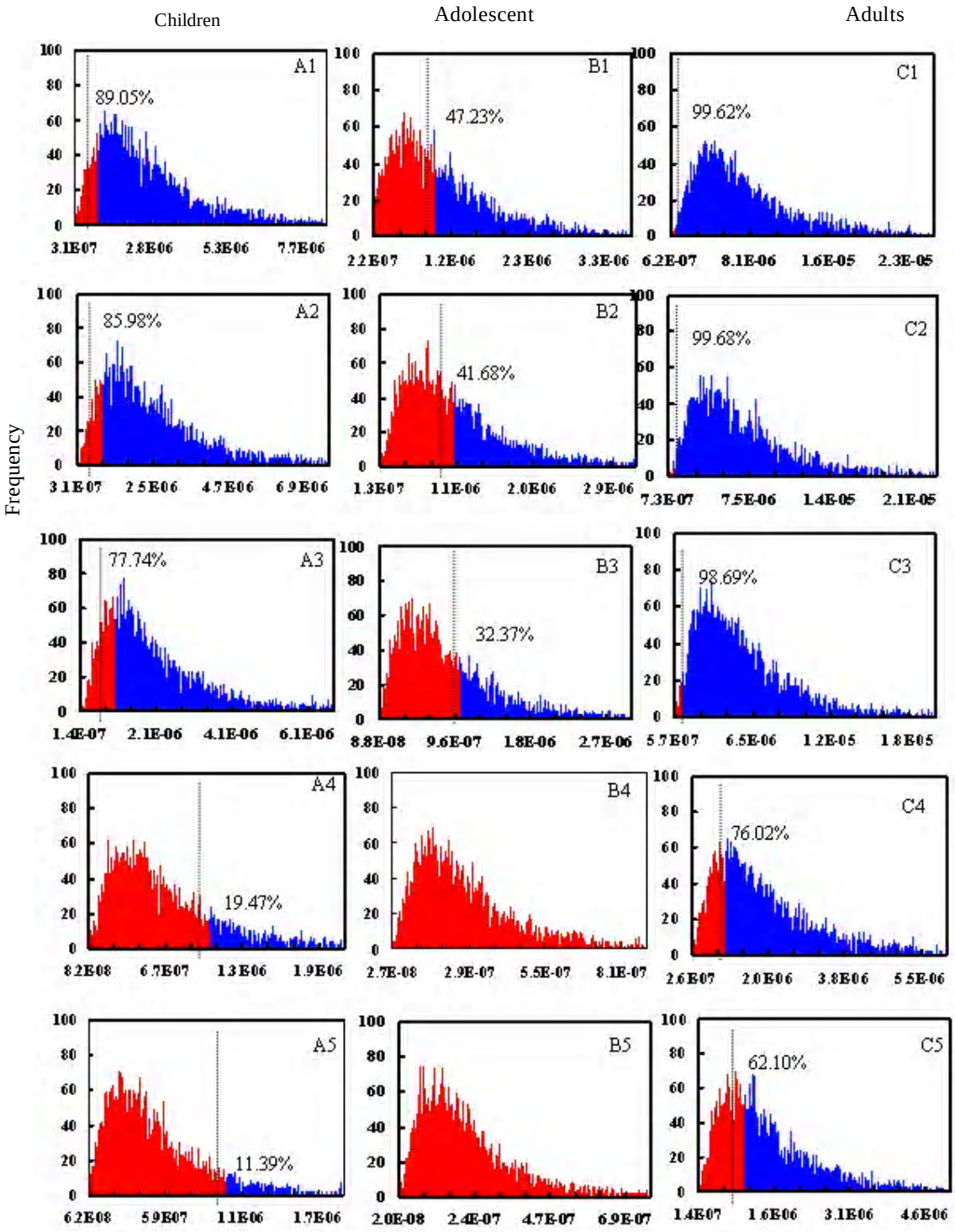

Fig. 3. A1–A5, B1–B5, and C1–C5 express the incremental lifetime cancer risk for age groups corresponding to children, adolescents and adults, respectively. We explored five scenarios with varying exposure frequencies: Scenario 1, with two weekend visits per week; Scenario 2, with one weekday and one weekend visit per week; Scenario 3, with two weekday visits per week; Scenario 4, with one weekend visit per week; and Scenario 5, with one weekday visit per week

evidence concerning different routes of exposure: intratracheal, inhalation, and dermal exposure. Thyssen *et al*. (1981) exposed male Syrian golden hamsters to BaP condensed onto sodium chloride particles at concentrations of 2.2, 9.5 and 46.5 mg BaP/m^3. Animals were exposed 4.5 h/d, 7d/wk for the first 10 weeks, then 3 h/d thereafter. Controls were unexposed. Tumors were not observed in the respiratory tract of the control group or the group that was exposed to 2.2 mg/m^3. The incidence of tumors in respiratory tract increased in a dose-dependent manner for the 9.5 and 46.5 mg/m^3 exposure groups (34.6 and 52%, respectively). The implications of this study. From the points of view of epidemiology and toxicology of BaP inhalation, the results of this study suggest that much more work needs to be done to have more complete data for risk assessment. Despite the large amount of data collected, the health effects of BaP inhalation need to take into account several covariates, such as smoking, diet, lifestyle, and genetic susceptibility. In fact, blood samples were collected to measure different biomarkers of exposure and of effect, and biomarkers of other possible sources of carcinogenic PAHs. Miao *et al*. (2014) conducted a cross-sectional study in Montreal with 200 volunteers (107 females and 93 males) aged 20-53 yrs. They suggested that PAH biomarker level (level of urinary 1-OHP) among females were higher than males, and that smoking was the strongest determinant. Hence, the sex-specific and individual characteristics still played an important role for consumer risk assessment.

CONCLUSION

This study estimated the lifetime exposure risk from particle-bound PAHs to Wenxin night market employees and consumers. Experimental measurements and probabilistic methods were adopted to quantify inhalation risks across five assumed exposure scenarios. As a result, the ILCR analysis demonstrated that the consumer exposure to cooking emissions in night markets is of minor health concern (ILCR"ÿ10^{-4}) compared to workers (ILCR 95% CI=1.03×10^{-5}–1.34×10^{-4}). Therefore, some protective measures are suggested to minimize human exposure, such as wearing mask of activated carbon and minimizing the frequency for night market visiting. Most importantly, the government should provide a comprehensives self-management plan to guide both the human health and economic development. Government agencies can counsel the night market vendors and vendors should be encouraged to adopt self-improvement steps such as to evacuate the exhaust into a water tank with bio-surfactant to improve the removal of PAHs installing effective mechanical exhaust vacuum or building a high exhaust fume hood above cooking ovens (Zhao *et al*., 2011). From the health points of view of resident, workers, and consumers, we suggest that the government should conduct the control strategy and regulation to manage the pollution emissions. These preliminary results can offer some important information to governments for understanding and controlling the pollutants in outdoor environments.

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