Subject Area 7.2: Evaluation of the impacts and interactions of chemicals in the laboratory or real environments, and their fate in biota, including animals and humans

Research Article

Respiratory Health of Road-Side Vendors in a Large Industrialized City*

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Abstract

Goal, Scope and Background. The literature reports a high prevalence of respiratory symptoms associated with exposure to motor vehicle exhaust emissions and people exposed to vehicle emissions are at risk of reduced lung function and cardiovascular performance. Although the effect of traffic emissions is a known risk to respiratory health, retailers are often situated along major roads in a busy urban environment to maximise customers. Shop assistants in an air-conditioned environment should be less exposed to traffic fumes and their lung function should be better preserved compared to 'unprotected' vendors exposed directly to vehicle emissions. The lung function of these two groups of workers has not previously been compared. The aims of this study are to determine if there is a difference in the concentration of respirable particles of diameter less than 10 micrometers (PM₁₀) inside and outside air-conditioned shops along a busy major road; and to compare the lung function parameters, blood lead levels and respiratory symptoms between road-side vendors directly 'exposed' to traffic fumes and vendors working in 'protected' air-conditioned shops along the same road.

Methods. Roadside vendors (n=33) and adjacent shop assistants (n=31) were recruited for the study in a district known to have high emissions and pollution measures. All subjects were asked to complete a questionnaire providing the frequency of their respiratory symptoms. Spirometry pulmonary function tests were conducted and exhaled carbon monoxide levels (E_{CO}), oxygen saturation and blood lead levels (BLL) were measured. PM₁₀ level was concurrently measured in the subject's working environment. Pulmonary function data and E_{CO} levels collected from a cohort of university staff aged ≥ 30 years (n=92) at a university campus were included for comparison.

Results. The concentration of particulate matter (PM₁₀) at the roadside (210 ± 70 µg/m³) was significantly higher than inside the shops (130 ± 40 µg/m³). There was no difference in lung function parameters or BLL between the groups, however the forced vital capacity of both groups of vendors was significantly lower than a 'control' cohort of academic institution personnel (n=92).

Discussion. This study illustrated that while the level of pollution improved with air conditioning, this may not be sufficient to prevent respiratory consequences. Our data suggests that a reduction in occupational exposure is not enough to protect these workers.

Conclusions. Air-conditioned work environment is insufficient to protect the respiratory system against the adverse effects of exposure to vehicle emissions.

Recommendations. The overwhelming effect of exposure during travel to and from work and at home cannot be underestimated. More stringent guidelines to control pollution appear necessary to protect the respiratory health of both shop-keepers and road-side vendors and further studies to explore the effect on respiratory health of the exposure to pollutants associated with commuting to and from work are warranted.

Keywords: Air pollution; blood lead; lung function; PM₁₀; respiratory health; road-side vendors

Introduction

The negative impact of air pollution on health is widely recognized (Guo and Jin 2003). The literature reports a high prevalence of respiratory symptoms associated with exposure to motor vehicle exhaust emissions (Tamura et al. 2003). Chronic occupational exposure to urban pollutants increases the risk of detrimental cardiovascular, respiratory and exercise performance (Volpino et al. 2004), and the rate of advancement of mortality associated with traffic air pollution is comparable to patients suffering chronic pulmonary and ischaemic heart disease (Finkelstein et al. 2004). Concentration of traffic pollutants was inversely related to the distance from the edge of the road (Cape et al. 2004), suggesting non-direct exposure to traffic fumes may offer some protection against ill effects of air pollutants.

In Hong Kong, an urbanised and metropolitan city, vehicle emission is one major source of air pollution and air quality is frequently less than recommended international standards (HKEPD 2005); many air-quality monitoring stations at different districts demonstrated concentrations of major air pollutants consistently higher than standardised air quality objectives (AQO). Some examples of hourly statistics of major air pollutants in Hong Kong were: sulphur dioxide ranged from 247–476 µg/m³, nitrogen oxides 811–2076 µg/m³, carbon monoxide 2350 to 5730 µg/m³, and respirable suspended particulates (continuous monitoring) 211–366 µg/m³ (HKEPD 2005). In an attempt to minimise the effect of air pollution on health, air quality guidelines have been instigated (ASHRAE 2005, EPA 2006), and in support of the Hong Kong Government's environmental policy, most public buses comply with Euro IV-standard emission guidelines. However, despite vehicle and power plant emission control programmes and government regulating guidelines for the manufacture of products containing volatile organic compounds, regional smog continues to worsen (EPD 2006).

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Although the effect of traffic emissions is a known risk to respiratory health, retailers are often situated along major roads in a busy urban environment to maximise customers. Shop assistants in an air-conditioned environment should be less exposed to traffic fumes and their lung function should therefore be better preserved compared to 'unprotected' vendors exposed directly to vehicle emissions. The lung function of these two groups of workers has not previously been compared.

The aims of this study are to determine if there is a difference in the concentration of respirable particles of diameter less than 10 micrometers (PM_{10}) inside and outside air-conditioned shops along a busy major road; and to compare the lung function parameters and respiratory symptoms between road-side vendors directly 'exposed' to traffic fumes and vendors working in 'protected' air-conditioned shops along the same road. As blood lead accumulation is related to exposure to PM_{10} (Carlisle and Sharp 2001), blood lead levels between these two groups were also compared.

1 Materials and Methods

Human subject ethics approval was granted by the involved University. Roadside vendors were recruited for study in the Mongkok district of Hong Kong. This district is known to have high emissions and pollution measures, as illustrated by the highest hourly statistics of sulphur dioxide at $476 \mu\text{g}/\text{m}^3$ and highest annual average of total suspended particulates of $112 \mu\text{g}/\text{m}^3$. The hourly statistics of nitrogen oxides was $1401 \mu\text{g}/\text{m}^3$, carbon monoxide $3680 \mu\text{g}/\text{m}^3$, and respirable suspended particulates $255 \mu\text{g}/\text{m}^3$ (HKEPD 2005). Mongkok is also a well known shopping area and has a culture of road-side vendors selling newspapers, food and confectionery.

Starting from one end of a main arterial road (Nathan road) in Mongkok, each road side vendor was invited in sequence to participate in the study. The nature of the study was explained and written consent was obtained prior to data collection. Demographic data such as age, gender, height and weight (measured by portable bathroom scale and tapes) of each participant were recorded. All subjects were also asked to complete a questionnaire providing the frequency of their respiratory symptoms including cough, sputum, runny nose, sore-throat and shortness of breath on mild exertion (using the categories, very frequent, frequent, rarely and very rarely); smoking history [current smoker, non-smoker and ex-smoker (stopped smoking for over 1 year)], number of years engaged in their present occupation and hours worked per day. With the road-side vendor's consent and after measurements were taken, the shop keeper in the adjacent shop was approached. Data from the road-side vendors and their adjacent shop-keeper were taken on the same morning. Subjects were excluded from the study if they reported known respiratory disease that required medical follow up or if they were receiving respiratory medication. It would contravene the Privacy Ordinance under the Laws of Hong Kong to independently verify a subject's medical condition without his consent. A request for positive confirmation of a negative report of illness was not practical and therefore it was assumed that the subjects' responses were accurate. None of the subjects reported respiratory illness and therefore no subject was excluded from the study.

All pulmonary function tests were conducted using two Microlab 3300 spirometers (Micro Medical Ltd, Kent, UK) and exhaled carbon monoxide (E_{CO}) levels measured with a Micro CO Meter (Micro Medical Ltd, Kent, UK). Oxygen saturation was determined by a finger pulse oximeter (Onyx 9500, Nonin Medical, Inc., Mn USA). Prior to the study, the CO meter was calibrated with a standard concentration of carbon monoxide. The volume of air in a 2-litre super syringe was measured for 100 full strokes by the two spirometers with a coefficient of variation of 1% or less. Proper technique for lung function measurement was demonstrated to each subject and the best of three trials recorded.

Measurement of blood lead level was conducted in strict adherence to a rigorous protocol recommended by Yee and Holtrop (1997). The concentration of particles with a diameter of 10 micrometers or less (PM_{10}) was measured using an aerosol monitor, DUSTTRAKTM (model 8520, TSI Inc. Mn), in the subject's working environment, concurrently with respiratory function measurements. During measurement, the aerosol monitor was placed next to where the road side vendor sat or in the centre of the shop, three samples were taken when a steady PM_{10} level was achieved after about 15 minutes. All measurements were performed at a similar time of the day and on sunny days.

To provide a Hong Kong reference norm for this study, the lung function and respiratory symptom data from a cohort of subjects, matched for age [≥ 30 years ($n=92$)], working in a university environment were extracted from a previous study, for comparison (Jones et al 2005).

Statistical analysis. One-way ANOVA was used to analyse the demographic data of road-side vendors, shop-keepers and university personnel; Chi-square analysis was used to compare gender distribution and proportion of smokers amongst the three groups. Group comparison of lung functions and E_{CO} level were made by fitting multiple regression models incorporating the effects of group, age, height, gender and smoking habit to allow for any difference in demographic characteristics. Respiratory symptoms were analysed with logistic regression models. Both regression analyses were followed by post-hoc group comparison. All adjusted mean values were evaluated at the overall mean of all 3 cohorts. Bonferroni adjustment was applied to minimise the overall type I error at 5%. Statistical package SPSS for Windows, version 12.0 (Chicago, IL) was used for the analysis. A p value of < 0.05 was set as the level of statistical significance.

2 Results

A total of 64 subjects (31 indoor shop-keepers and 33 outdoor road-side vendors) were recruited to the study. The period of data collection took 3 months. No subjects were excluded because of known respiratory disease. The age, body mass index, years of work and duration of work hours for the two groups were similar (Table 1). The number of smoker, non-smoker and ex-smoker road side vendors, shop-keepers and in the university group were 6:22:5, 12:18:1 and 12:77:3, respectively. The concentration of particulate matter (PM_{10}) in the roadside shops ($130 \pm 40 \mu\text{g}/\text{m}^3$) was significantly lower than outside the shops ($210 \pm 70 \mu\text{g}/\text{m}^3$) ($p<0.0005$). The blood lead levels (BLL) in road side ven-

Table 1: Demographic data of road-side vendors, shop-keepers and the university personnel. Data are mean $\pm$ SD except for number of females and smokers

	Road-side Vendors (N=33)	Shopkeepers (N=31)	University personnel (N=92)	P value for road-side vendors and shop-keepers comparison	P value for overall comparison
Gender – number of female	17 (51.5%)	17 (54.8%)	38 (41.3%)	0.886	0.214
Mean age (yrs)	45.1 $\pm$ 13.1	42.8 $\pm$ 10.6	41.3 $\pm$ 7.5	1.000	0.291
Mean BMI (kg/m ²)	22.8 $\pm$ 3.1	22.7 $\pm$ 3.3	22.6 $\pm$ 2.4	1.000	0.900
Number of smokers	6 (18.2%)	12 (38.7%)	12 (13.0%)	0.068	0.002*
Number of non-smokers	22 (66.7%)	18 (58.1%)	77 (83.7%)	0.478	
Number of ex-smokers	5 (15.2%)	1 (3.2%)	3 (3.3%)	0.198	
Years of work (yrs)	11.4 $\pm$ 11.7	13.4 $\pm$ 10.8	NA	0.464	NA
Duration of work hours (hrs)	9.92 $\pm$ 3.18	10.08 $\pm$ 0.97	NA	0.789	NA
Blood lead level (μ g/dL)	5.61 $\pm$ 1.53	5.14 $\pm$ 1.27	NA	0.183	NA

BMI = body mass index

NA = data not available

* significant difference in number was observed between university cohort and shopkeepers only

Table 2: Lung function and exhaled carbon monoxide levels [data are adjusted mean (SE) values*]

	Road-side Vendors (1)	Shopkeepers (2)	University personnel (3)	P value for pairwise comparison		
				1 vs 2	1 vs 3	2 vs 3
Forced expiratory flow in 1 st second (FEV ₁) (l)	2.63 (0.07)	2.62 (0.07)	2.81 (0.05)	1.000	0.089	0.053
Forced Vital Capacity (FVC) (l)	2.84 (0.09)	2.79 (0.08)	3.27 (0.06)	1.000	< 0.0005	< 0.0005
FEV ₁ /FVC (%)	92.66 (1.40)	93.87 (1.29)	86.60 (0.94)	1.000	0.001	< 0.0005
Peak expiratory flow (l/s)	6.56 (0.34)	6.42 (0.31)	6.54 (0.23)	1.000	1.000	1.000
Exhaled carbon monoxide level (ppm)	7.92 (1.24)	6.69 (1.14)	8.81 (0.89)	1.000	1.000	0.422

* Evaluated at the overall mean age (42.34 yrs) and height (1.63 m). Analysis adjusted for age, gender, height and smoking habits.

Table 3: Subjects with frequent symptoms in each cohort. Analysis adjusted for age, gender, height and smoking habits. Data are expressed as percentages except for p values

Symptoms	Road-side Vendors (1)	Shopkeepers (2)	University personnel (3)	P value for Pairwise comparison		
				1 vs 2	1 vs 3	2 vs 3
Cough	45.2	48.4	19.3	0.895	0.008	0.006
Sputum	38.7	38.7	21.0	0.665	0.020	0.044
Shortness of breath	54.8	71.0	11.6	0.239	< 0.0005	< 0.0005

dors and shopkeepers were similar (see Table 1). Further analysis showed there was no difference in the BLL between smokers (5.69 $\pm$ 0.33 μ g/dL in male; 4.95 $\pm$ 0.56 μ g/dL in female) and non-smokers (6.14 $\pm$ 0.47 μ g/dL in male; 5.00 $\pm$ 0.26 μ g/dL in female) (p=0.433 & 0.934 in male and female respectively). There was no difference in FEV₁ and reported symptoms between smokers and non smokers (p=0.097, 0.08, 0.544 and 0.664 for FEV₁, frequency of cough, sputum and shortness of breath on mild exertion, respectively). However, any inference derived from a comparison of these data could be meaningless because of the small number of smokers.

All lung function parameters and frequency of respiratory symptoms were similar between the study groups, however the forced vital capacity of shopkeepers and road-side vendors was lower than the university cohort (p<0.0005) (Table 2). Furthermore, both the shopkeepers and road-side vendors had a higher frequency of complaints of cough, sputum and shortness of breath on mild exertion compared to the university personnel (Table 3).

3 Discussion

The main aim of this study was to compare the lung function between shopkeepers working in air-conditioned environment and road-side vendors exposing to direct traffic fume. Results of this study showed that the lung function of both groups was similar. Both groups of subjects were of similar age group and had worked in their present job for over 10 years, thus it is considered appropriate to associate their present lung function with their work environment. To establish whether the lung function of these subjects were 'normal', their data were compared with a group of personnel working in an university environment where their habitat was not amongst traffic fumes. Our data confirmed that roadside shopkeepers and vendors had a reduced lung capacity and were more prone to shortness of breath on mild exertion compared to subjects working in an environment not exposed to vehicle emissions. Dyspnoea, a sensation of shortness of breath, is one common feature of patients with decreased lung capacity such as pulmonary fibrosis or interstitial lung disease (West 2003), we hypothesise that the more frequent complaint of shortness of

breath on exertion in our cohort of shopkeepers and road side vendors was associated with their decreased lung capacity compared to the University cohort. People exposed to intense traffic fumes are at risk of respiratory symptoms, reduced lung function (Polosa 2001) and reduced exercise performance (Volpino et al. 2004). The similar frequency of complaint of respiratory symptoms for both road-side vendors and shopkeepers suggested that the air-conditioned environment did not sufficiently protect our shopkeepers from the traffic fumes. Although statistically non-significant, a higher percentage of shopkeepers compared to road-side vendors complained of shortness of breath on mild exertion (see Table 3). It is possible that the job nature for road-side vendors was more physically demanding compared to shopkeepers because they regularly had to stack and move heavy piles of newspaper. We speculate that in the course of their work, shopkeepers perform less regular strenuous physical work than road-side vendors and therefore would feel more stressed by exertional demand. Without applying a standard stress test to determine cardiopulmonary fitness, these subjects cannot be objectively compared.

Introduction of unleaded petrol was shown to be able to reduce BLL of government employees in Singapore from 7.7 to 6.6 $\mu\text{g/dL}$ (Neo et al. 2000, Ooi et al. 1991). Despite most public buses in Hong Kong complying with Euro IV-standard emission guidelines, our recorded road-side PM_{10} level was higher than the air quality standard for PM_{10} recommended by the United States Environmental Protection Agency (150 $\mu\text{g/m}^3$). It was therefore not surprising to find that the lung function parameters of our road-side vendors were worse than an adult cohort of university personnel. However, although the mean PM_{10} level inside the air-conditioned shops was within the recommended air quality standards, the shop-keepers' measured lung function parameters were the same as the roadside vendors who were exposed directly to vehicle emissions. It would seem that although the filtering of particulate matter in the shops appeared effective in lowering the indoor PM_{10} level, the shop-keepers suffered similar respiratory health effects. Blood lead accumulation during exercise is related to exposure to PM_{10} (Carlisle and Sharp 2001). Deterioration in health occurs at lead levels between 30 to 50 $\mu\text{g/dL}$ (Department of Health, NY); despite a high level of outdoor PM_{10} concentration, the BLL of our road-side vendors and shopkeepers were under the WHO limit [48 $\mu\text{g/dL}$] (WHO 1987) and compared favourably to that of road traffic constables in Pakistan (27.3 $\mu\text{g/dL}$) (Agha et al. 2005). While smoking is one source of lead exposure (Papanikolaou et al. 2005), our data demonstrated that there was no difference in BLL between our smokers and non-smokers irrespective of gender. To ensure that the result of between-group lung function comparison was not influenced by the number of smokers in each group, multiple regression models were adopted taking age, height, gender and smoking history into consideration during the analysis. We hypothesise that the similar respiratory health patterns illustrated by shop-keepers and road-side vendors were a result of their overall 'habitat', including unavoidable chronic exposure to vehicle emissions during travel to and from work. Our hypothesis is supported by the finding that although $\text{PM}_{2.5}$ and NO_2 levels were higher in urban compared with rural areas, the incidence of acute respiratory symptoms was the same (Simoni et al.

2004). Unfortunately we were unable to measure the level of $\text{PM}_{2.5}$ and NO_2 levels in this study. Whether the respiratory health of road-side vendors and shop keepers was determined by their overall habitat needs to be further investigated.

The literature reports an increasing risk of allergy, respiratory disorders and lung function impairment associated with indoor air pollution (Viegi et al. 2004), and recommends that the adverse health effects of indoor pollution should be closely observed. In urbanised city like Hong Kong, poor ventilation and inappropriate filtering of outdoor pollutants rather than combustion of oil, gas, kerosene, coal or wood are common causes of indoor pollution. Our study shows that despite the air quality within the air-conditioned shops being within acceptable limits, the vital capacity in shop-keepers was reduced by a similar amount to the road-side vendors suggesting that chronic 'low level' air pollution may be just as deleterious as exposure to the acceptable upper limit for PM_{10} .

4 Limitation of the Study

The aim of including the university (academic staff) cohort for comparison was to establish a lung function reference for road-side vendors and shopkeepers. This comparison assumed that the lung function of the university cohort would not be exposed to more than usual road-side pollutants and therefore this cohort could provide 'baseline' data for a specific age group. However, for legal reasons, it was not possible to independently verify the accuracy of their reported responses and this could possibly be a potential source of error.

We have considered it appropriate to associate lung function with working environment as all of the subjects had worked in their present job for over 10 years. Unfortunately we did not explore their work history with a degree of thoroughness which might have revealed any potential confounding variables associated with a previous work setting.

As the number of smokers in each cohort was small, we were unable to draw any proper conclusions on the impact of smoking on the lung function in our subjects.

5 Conclusions

In summary, this study illustrated that while the level of pollution improved with air conditioning, this may not be sufficient to prevent respiratory consequences, and a reduction in occupational exposure is not enough to protect these workers. The overwhelming effect of exposure during travel to and from work and at home cannot be underestimated. More stringent guidelines to control pollution appear necessary to protect the respiratory health of both shop-keepers and road-side vendors and further studies to explore the effect on respiratory health of the exposure to pollutants associated with commuting to and from work are warranted.

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I first met Otto Hutzinger in 1970 when he began his career at the National Research Laboratories in Halifax, Nova Scotia and I was doing the same at the University of Waterloo, Ontario Canada. From the beginning, he was an enormous help to me in my career. But more important, over the intervening 38 years we have had an enduring friendship in which we shared our personal and professional lives very closely and deeply. I took several sabbatical leaves with him, first at the University of Amsterdam and then twice at the University of

Bayreuth. We attended over 100 conferences together at which we shared a room, our thoughts and hopes for the future. He built a home near me in Arizona so we could strengthen our friendship over the many years he visited there. I spent a lot of days at his various homes in Europe. Truly, he is my best friend. The genius behind his many accomplishments is an ability to motivate people and encourage them to achieve their utmost. The evidence of that success is apparent, especially in the enduring Dioxin conferences and the scientific publication field. The world is a better place thanks to his presence.