Air Pollution and Risk of Respiratory and Cardiovascular Hospitalizations in the Most Populous City in Vietnam

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Abstract

Air pollution has become an alarming issue in Vietnam recently; however, there was only one study so far on the effects of ambient air pollution on population health. Our study aimed to investigate the short-term effects of air pollutants including PM_{10}, NO_2, SO_2, and O_3 on respiratory and cardiovascular hospitalizations in Ho Chi Minh City (HCMC), the largest city in Vietnam. Data on hospitalization from the two largest hospitals in HCMC and daily records of PM_{10}, NO_2, SO_2, O_3 and meteorological data were collected from February 2004 to December 2007. A time-series regression analysis with distributed lag model was applied for data analysis. Changes in levels of NO_2 and PM_{10} were strongly associated with hospital admissions for both respiratory and CVD; whereas levels of SO_2 were only moderately associated with respiratory and CVD hospital admissions and O_3 concentration was not associated with any of them. For a 10 $\mu g/m^3$ increase of each air pollutant, the risk of respiratory admissions increased from 0.7% to 2% while the risk of CVD admissions increased from 0.5% to 4%. Females were found to be more sensitive than males to exposure to air pollutants in regard to respiratory diseases. In regard to cardiovascular disease, females (RR, 1.004, 95% CI, 1.001-1.007) had a slightly higher risk of admissions than males (RR, 1.003, 95% CI, 1 -1.005) to exposure to NO_2. In contrast, males (RR, 1.007, 95%CI, 1-1.01) had a higher risk of admission than females (RR, 1.004, 95%CI, 1.001-1.007) to exposure to PM_{10}. People in the age group of 5-65 year-olds had a slightly higher risk of respiratory admissions caused by air pollutants than the elderly (65+ years old) while a significant effect of PM_{10} on the risk of cardiovascular admissions was found for the elderly only.

Key words: air pollutants, exposure, respiratory diseases, cardiovascular diseases, hospital admission, Vietnam

1. Introduction

Ambient air pollution, which is mainly caused by the combustion of non-renewable fossil fuels for electricity generation, transport and industry, has been worsening over the past five decades (Rowshand et al., 2009; Ying et al., 2015). Many epidemiological studies have indicated that air pollutants such as particulate matter (PM), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and ozone (O_3) are responsible for increasing mortality and morbidity in different populations around the world, especially from respiratory and cardiovascular diseases (CVD) (Beckerman et al., 2012; Brunekreef and Holgate, 2002; Costa et al., 2014; Curriero et al., 2002; Haines et al., 2000; Rowshand et al., 2009; Samet and Krewski, 2007; Tsai et al., 2014; Tsangari et al., 2016). A global study of the burden of diseases in the year 2000 suggested that nearly two thirds of the estimated 800,000 deaths and 4.6 million lost years of healthy life worldwide caused by exposure to air pollution in that year were in the developing countries of Asia (World Health Organization, 2002) and this phenomenon has continued until very recently (World Health Organization, 2014). Nevertheless, research on the relationship between air pollutants and health effects have been conducted predominantly in developed countries rather than in the developing countries of Asia, where the poorer population is exposed to higher levels of air pollution and has less capacity to cope with air pollution related issues (HEI International Scientific Oversight Committee, 2010). Therefore, evaluation of the impacts of air pollution on population health in developing Asian countries heavily relies on extrapolation from the results of studies conducted in developed countries and is therefore subject to great uncertainty (Cohen et al., 2004; HEI International Scientific Oversight Committee, 2010).

Ho Chi Minh City (HCMC) is the largest and most populous city in Vietnam where growing industrial activity and vehicular traffic have led to an increase in all aspects of environmental pollution, of which air pollution is a major issue impacting considerably on the quality of life of its residents (Nguyen and Pham, 2002). The major source of air pollution in urban areas of HCMC is the large number of motor vehicles. A previous investigation demonstrated that a large proportion of total air pollutants (CO, 90%; Hydrocarbon, 60%; $NO_{x,}$ 50%) in HCMC could be attributed to motor vehicles (CEFINEA, 2001; Department of Science, 2001). The results from monitoring stations on the road sites in HCMC show that the levels of suspended particulate matter are always 2-6 times higher than the allowable concentrations (CEFINEA, 2001). Nevertheless, studies on the relationship between air pollution and its effects on the population health have rarely been carried out in HCMC or in Vietnam. To date, only one epidemiological study on this topic (Mehta et al., 2013) has been published, It found a positive association between air pollution and elevated risk of hospital admission due to acute lower respiratory infection (ALRI) among young children in HCMC. However, no study of the health effects of air pollution among adult residents has been carried out. Although not a susceptible group, adults are usually exposed to higher levels of air pollution, especially to air pollution generated by vehicular traffic due to their work-related travel activities. The majority of residents in HCMC travel by motorbikes, which means that they are directly exposed to air pollution in traffic and traffic jams. Therefore, it is important to understand the impact of such exposure on the health of the population other than children in this large metropolitan city.

The objective of this study was thus to evaluate the short-term effects of air pollutants including particulate matter with an aerodynamic diameter less than 10 µm (PM_{10}), NO_2, SO_2, and O_3 on the rate of hospitalization due to respiratory and CVD in HCMC.

2. Methods

2.1 Research location

The study was conducted in HCMC in the South of Vietnam with a tropical climate. The total area of the city is 2692 km^2 including 19 urban and 5 suburban districts with a total population of more than 7 million, i.e. about 8.4% of the total population of Vietnam. The population density of HCMC is 2660 people per km^2 (Huyen, 2012). HCMC has two seasons: the rainy season (May-November) and the dry season (December-April). The city experiences 2400-2700 hours of sunshine per year, and average rainfall is about 1800 mm annually during the rainy season (Asian Development Bank, 2009). In recent years, the population of HCMC has been increasing rapidly due to immigration from other provinces, leading to high density of road traffic. HCMC accounts for approximately 40% of vehicles of the whole country.

2.2 Data collection

- Air quality and meteorological data:

Air quality data was obtained from the archive of the Air Quality Monitoring System, Centre for Environmental Monitoring and Analysis, HCMC Environmental Protection Agency (HEPA) for the period from 1st February, 2004 to 31st December, 2007. Data from other periods were not included due to the high number of missing values.

Hourly air quality data were collected from 4 stations, namely D2 (District 2), QT (Go Vap District), Zoo (District 1) (background) and TSH (Phu Nhuan District). These monitoring stations were considered to provide background (Zoo site) and residential air quality data on the 4 parameters of PM_{10}, SO_2, NO_2 and O_3. The location of the four monitoring stations is shown in Fig 1.

Daily, city-level exposure estimates of PM_{10}, NO_2, SO_2 and O_3 (maximum 8-h moving average) were generated using hourly data from the above monitoring stations.

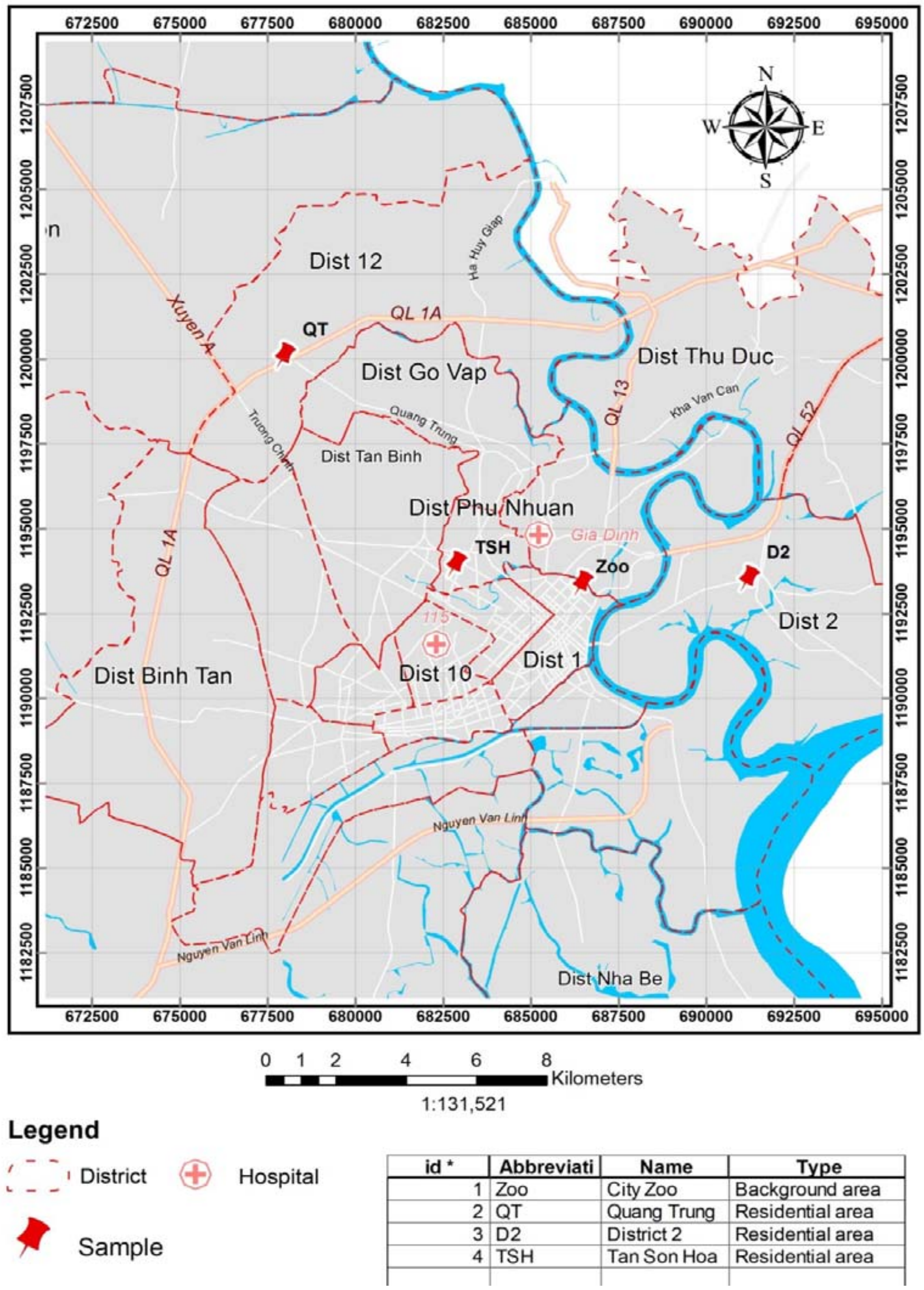

Fig. 1. The locations of monitoring sites and the two hospitals involved in this study.

A 75% completeness criterion was applied in aggregate data calculation. Thus, if less than 18 hours of PM_{10}, NO_2 and SO_2 concentration data were available in a day then the daily average concentration for the day was considered as ‘missing’ data. For O_3, if less than 6 hours of concentration data were available, then the maximum 8-hour moving concentration for the day was classed as ‘missing.’ If the daily average concentration computed from D2 station was available, it was chosen as the value for daily city-level concentration. Otherwise, an average of values from the other stations was calculated and used. If daily average concentration of any parameter was not available in any stations, the daily city-level concentration for that day was classed as 'missing'. About 3%-26% of all observations were missing values during the study period of 1826 days (3% for O_3, 7% for NO_2, 14 % for PM_{10} and 26% for SO_2). All missing values were excluded from the analysis.

Daily meteorological data were obtained from the Southern Regional Hydro-Meteorological Center for the same period (1 February 2004 – 31 December 2007). The data were the daily records from the hydro-meteorological station located in the central district of HCMC (longitude, 106^{o}39'59.75 East; latitude, 10^{o}47'47.48 North), and comprised daily minimum, maximum, and average temperatures (^{o}C) and minimum, maximum and average relative humidity (%).

- Hospital admissions

Data on hospitalizations were extracted from the daily hospital admissions due to respiratory diseases (ICD-10 Codes: J00-99 with exclusion of lung diseases due to external agents, J60-70) and CVD (ICD-10 Codes: I00-99 with exclusion of acute rheumatic fever, I00-02 and chronic rheumatic heart diseases, I05-09) from 1 February 2004 to 31 December 2007 in the two largest hospitals in HCMC, Gia Dinh People's Hospital and 115 People's Hospital (Fig. 1). These multi-faculty hospitals have 1200 and 1600 beds respectively. Data extracted from the admission records include primary and discharge diagnoses, date of admission, date of discharge, age, sex, and the district of residence of individual patients. This study was approved by the Griffith University Human Research Ethics Committee.

2.3 Data analysis

We used time-series regression analysis (Bhaskaran et al., 2013) to examine the short-term association between air pollutants (PM_{10}, NO_2, SO_2, and O_3) and hospital admissions (respiratory and CVD) using Generalized Linear Model (GLM) and Distributed Lag Model (DLM) with the family of Poisson distribution. A GLM model (Equation 1) was used to quantify the air pollutant – admission relationship, in which the dependent variable was the daily counts of hospital admissions and the main exposure variable was the daily level of each individual air pollutant. In order to examine the delayed effect of air pollutants, we used a DLM for lag up to 4 days (0-3 days) which has been proven to be significant in most previous studies (Cheng et al., 2015; Guo et al., 2009; Le Tertre et al., 2002; Ying et al., 2015). We used a flexible spline function of time with 7 knots per year to control for the long-term trend and seasonal effects (Bhaskaran et al., 2013) and natural cubic spline functions with 4 degrees of freedom to adjust for the effects of temperature and relative humidity. A variable of "Day of the week" was also adjusted in the model to adjust for the day effect on hospital admissions. The analysis of air pollutant – admission relationship was conducted separately for genders (male, female) and age groups (5-65, and 65+ year-olds). To minimize the co-linearity effect, we modelled air pollutants individually.

$$Y_t \sim Poisson\ (\mu_t)$$

$$Ln(\mu_t) = \alpha + \sum_{t=0}^{3} \beta_i AP_{t,l} + s(AT, 4\ df) + s(AH, 4\ df) + s(time, 7 * year) + \gamma DOW$$

Equation 1

where, Y_t is the observed daily count of hospital admissions (respiratory or cardiovascular admissions) on day t and l is the lag days; AP is the daily level of the air pollutant (PM_{10}, NO_2, SO_2, or O_3); AT is the average daily temperature; AH is the average daily relative humidity; s is a spline function; and DOW is day of the week.

3. Results

Table 1 summarizes the descriptive statistics of research variables whereas Fig. 2 describes the temporal patterns of air pollutants and hospital admissions. The daily levels of PM_{10} ranged from 11.6 - 209.9 µg/m^3 with a mean of 74 µg/m^3, which is lower than the standard (150 µg/ m^3) of the Vietnam National Technical Regulation on Ambient Air Quality (MONRE, 2013) but higher than the European Air Quality Standard or the WHO guideline (50µg/ m^3, in both) (AQS; WHO, 2005). The number of days which exceeded the Vietnamese national standard was 36 days (2.5% of the study period) while the number of days which exceeded the WHO standard guideline (50 µg/ m^3 24-hour mean) was 1,126 days (79% of the study period). The daily level of other air pollutants ranged from 2.8 – 55.2 µg/m^3 (mean, 18.9 µg/m^3) for NO_2, 1.4 – 192 µg/m^3 (mean, 30.3 µg/m^3) for SO_2, and 0.9-117 µg/m^3 (mean, 40 µg/m^3) forO_3. The levels of PM_{10}, NO_2, and O_3 were higher in the dry season (83, 20, 48 µg/m^3 respectively) than in the wet season (68, 18, 34 µg/m^3). However, the opposite result was found for SO_2 (27 µg/m^3 in the dry season versus 32 µg/m^3 in the wet season).

In terms of climatic condition, the average daily temperature during the study period ranged from 23 to 32^{o}C (mean, 27 ^{o}C). The total number of days with temperature ≥ 30.5^{o}C (95th percentile) was 56 (mean, 14 days/year). The average daily humidity ranged from 51 to 97% (mean, 70%).

In terms of hospital admissions, the total admissions for cardiovascular and respiratory diseases during the study period were 43,595 (daily mean, 31) and 33,045 (daily mean, 23), respectively. While male and female groups shared similar values for daily mean of hospital admissions for the two causes, there were differences in cause-specific admissions for the two age groups. The number of respiratory admissions was higher in the age group of 5-65 year-olds than in the elderly age group (65+ year-olds). At the same time, the number of cardiovascular admissions was higher in the elderly group than in the younger group (Table 1). The number of both cardiovascular and respiratory admissions gradually increased from 2004 to 2007 (data not shown here).

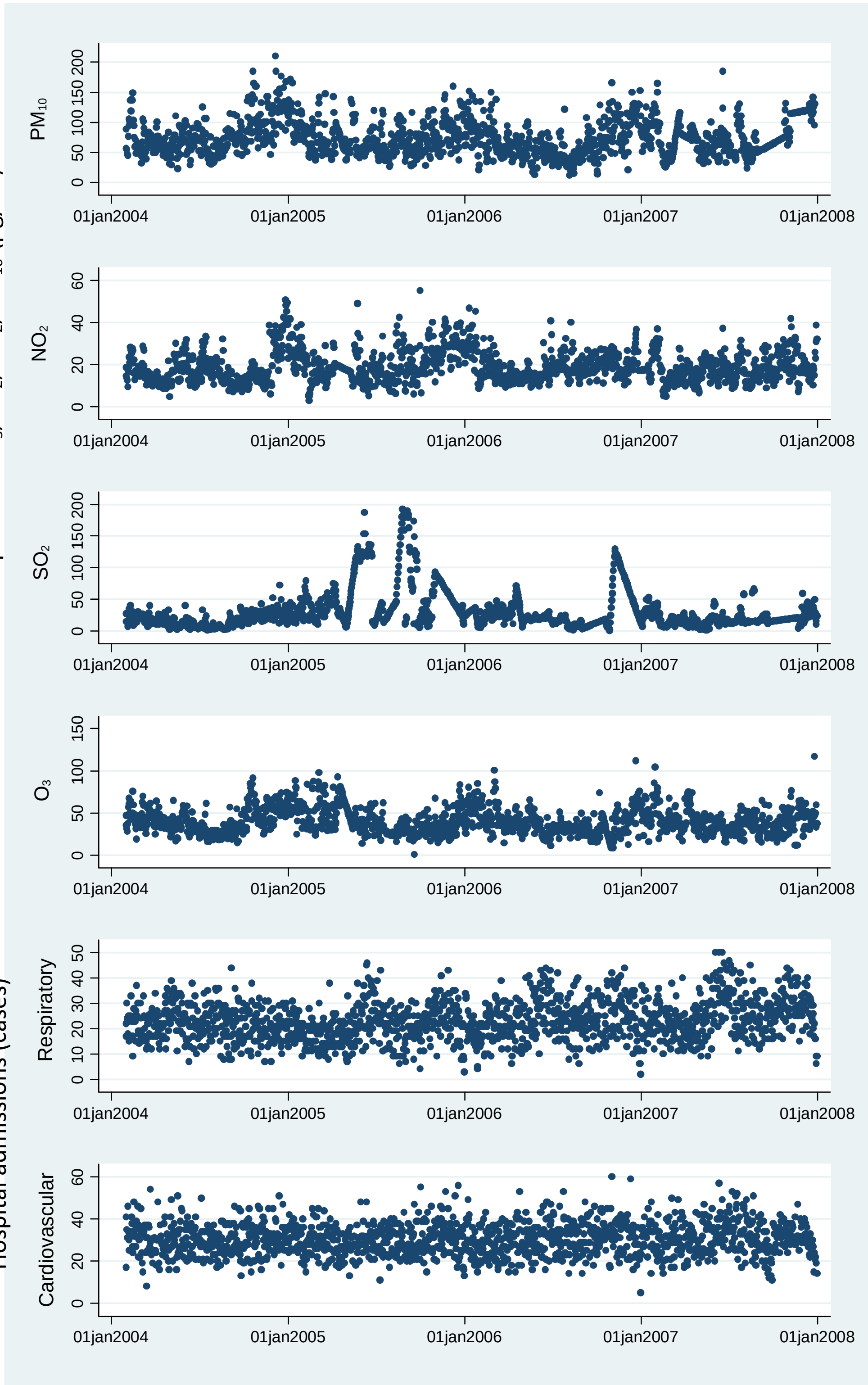

Fig. 2. Plots of levels of air pollutants and hospital admissions during the study period

Table1. Descriptive Statistics of air pollutants, weather conditions, and hospital admissions

	Frequency distribution			Minimum	Maximum	Mean (SD)
	25th	50th	75th			
Air pollutants						
PM_{10} (μg/m^3)	51.9	68.1	91.4	11.6	209.9	74.0 (29.7)
NO_2 (μg/m^3)	13.6	17.6	22.7	2.8	55.2	18.9 (7.4)
SO_2 (μg/m^3)	13.1	20.2	33.6	1.4	192	30.3 (30.5)
O_3 (μg/m^3)	28.8	37.0	48.9	.9	117	40.0 (15.6)
Weather conditions						
Temperature (^{o}C)	27.1	28.1	29	23.1	32	28.1 (1.4)
Humidity (%)	70	75	80	51	97	74.8 (7.3)
Respiratory admissions						
All	17	22	28	2	50	23 (8)
Male	9	11	14	1	31	12 (5)
Female	8	11	14	1	29	11 (5)
5-65 year-olds	12	16	21	1	39	17 (7)
65+ year-olds	4	6	8	0	19	6 (3)
Cardiovascular admissions						
All	25	30	35	5	67	31 (8)
Male	11	13	15	2	33	14 (5)
Female	13	17	20	3	34	17 (5)
5-65 year-olds	9	12	15	2	32	13 (4)
65+ year-olds	16	18	20	3	35	18 (5)

Overall, the effects of air pollutants on the risk of hospital admissions for respiratory diseases were found to be significant for PM_{10}, NO_2, and SO_2 at lag 0 day only; whereas O_3 did not cause any significant effect.

3.1 Effects of air pollution on respiratory admissions

Figure 3 presents the association between air pollutants and respiratory admissions. At lag-0 day, the risk of respiratory admissions increased by 0.7% (Relative risk (RR), 1.007; 95% CI, 1.002-1.013) for a 10 μg/m^3 increase in PM_{10}; by 8% (RR, 1.08; 95% CI, 1.06-1.011) for a 10 μg/m^3 increase in NO_2, and by 2% (RR, 1.02; 95% CI, 1.01-1.03) for a 10 μg/m^3 increase in $SO_{2.}$ Females (PM_{10}: RR, 1.01, 95% CI, 1.001-1.02; NO_2: RR, 1.12; 95% CI, 1.09-1.15; SO_2: RR, 1.03; 95% CI, 1.02-1.05) were found to be more sensitive to exposure to air pollutants than males (PM_{10}: RR, 1.0008, 95% CI, 0.999-1.009; NO_2: RR, 1.05; 95% CI, 1.02-1.09; SO_2: RR, 1.01; 95% CI, 0.999-1.03) in regard to respiratory diseases. The people in the age group of 5-65 year-olds (NO_2: RR, 1.1; 95% CI, 1.07-1.12; SO_2: RR, 1.03; 95% CI, 1.01-1.04) had a slightly higher risk of respiratory admissions caused by NO_2 and SO_2 than the elderly (NO_2: RR, 1.05; 95% CI, 1.001-1.01; SO_2: RR, 1.011; 95% CI, 1-1.03). The harvesting effects were observed at the lag 0 (high) & lag 1 (low) for PM_{10} and NO_2 for all groups (Fig. 3).

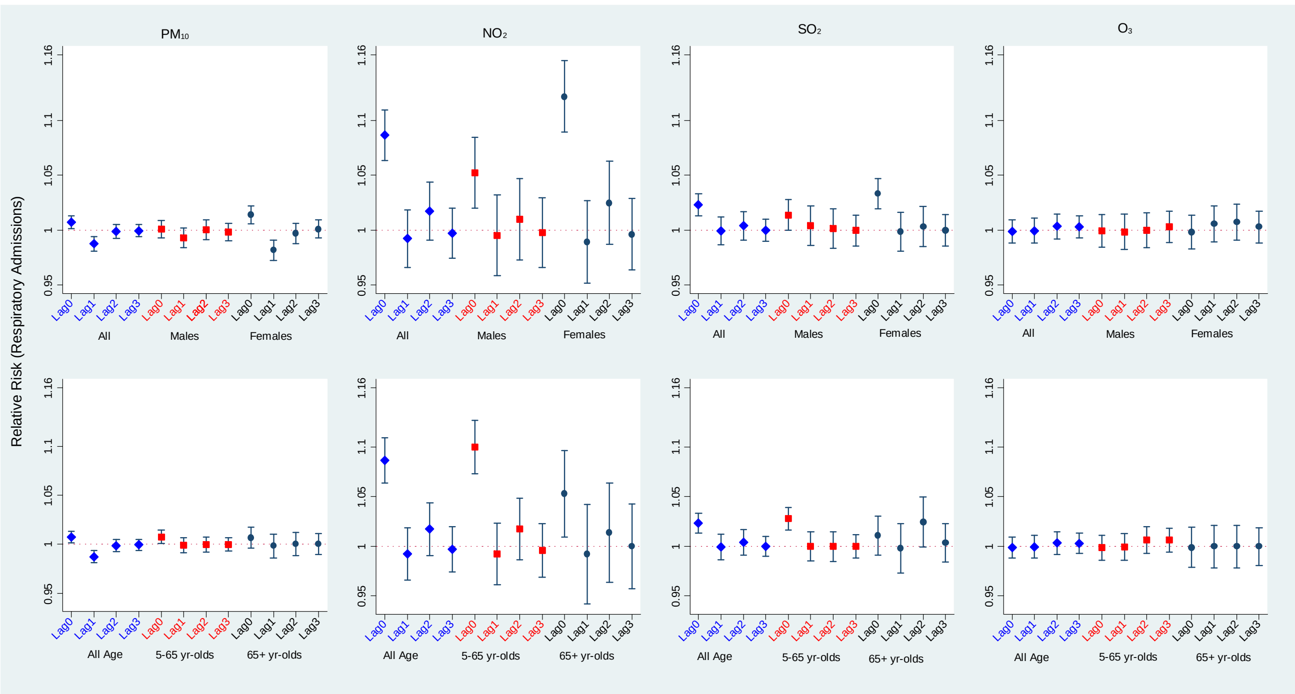

Fig. 3. Relative risk of respiratory admissions for an increase of 10 μg/m^3 in air pollutants

3.2 Effect of air pollution on cardiovascular admissions

Figure 4 shows the association between air pollutants and cardiovascular admissions. Significant effects were observed for PM_{10}, NO_2 and SO_2 at lag-0 day; whereas O_3 did not have any significant association with cardiovascular admissions. An increase of 10 $\mu g/m^3$ in PM_{10} was associated with a 0.5% (RR, 1.005, 95% CI, 1-1.009) increase in risk of CVD admission, and an increase of 10 $\mu g/m^3$ in NO_2 was associated with a % (RR, 1.02, 95% CI, 1-1.06) increase in risk of CVD. In relation to increased NO_2, females (RR, 1.004, 95% CI, 1.001-1.007) had a slightly higher risk of cardiovascular admissions than males (RR, 1.003, 95% CI, 1 -1.005). In contrast, in relation to increased PM_{10}, males had a higher risk of cardiovascular admission (RR, 1.007, 95%CI, 1-1.01) than females (RR, 1.004, 95%CI, 1.001-1.007). In terms of age, a significant association between PM_{10} and risk of cardiovascular admissions was found with the elderly (65+ year-olds) (RR, 1.008, 95% CI, 1.001-1.01) while this was non-significant for the 5-65 year-olds age group. However, the relationship between NO_2 and cardiovascular admissions was statistically significant for both age groups (5-65 year-olds: RR, 1.05, 95% CI, 1.02-1.08; 65+ year-olds: RR, 1.04, 95% CI, 1.01-1.06). The phenomenon was more pronounced for the 5-65 year olds group. The harvesting effects were also observed at lag 0 (high) and lag 1 (low) for PM_{10} and NO_2 for all groups (Figure 4).

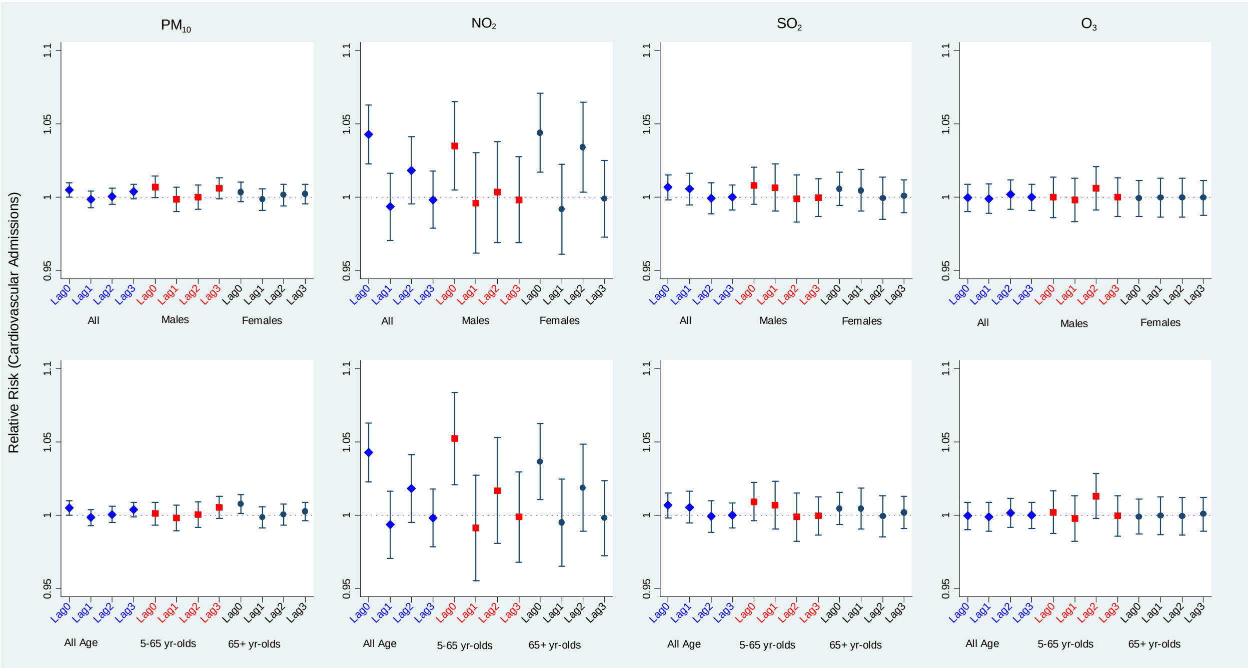

Fig. 4. Relative risk of cardiovascular admissions for an increase of 10 µg/m^3 in air pollutants

4. Discussion

This is the first study to investigate the effects of ambient PM_{10} and other gaseous pollutants (NO_2, SO_2 and O_3) on hospital admissions due to respiratory and CVD of the adult population at the two largest general hospitals in the metropolitan area of HCMC . As reported previously by Mehta et al. (2013), the levels of air pollutants in HCMC varied according to the seasons with higher levels of pollutants during the dry season and lower levels in the rainy season, which could influence the health outcomes. The observed seasonal trends for air pollution variables were consistent with differences in meteorological conditions where frequent rainfalls in the rainy season help clean the atmosphere of air pollutants. Burning/combustion probably did not contribute to the variation as the temperature in HCMC is stable around 28 ^{o}C all year round, which means that heating is not required (Table 1 or Phung et al., 2016).

However, there was not any clear trend in the daily CVD and respiratory admissions to the two hospitals during the study period. This contrasts with the seasonal trend (dry versus rainy seasons) observed in the data for admissions due to acute lower respiratory infections of children

(0-5 year-old) reported previously in HCMC during the same period (Mehta et al. 2013). It is probable that the adult population observed in this study is not as susceptible to seasonal variation as the new born and toddlers population in HCMC.

There was no difference between males and females in respiratory admissions but slightly higher in females in regards to CVD admissions (Table 1). But it is noted that the elderly group (65+ year-olds) is very susceptible to CVD with a higher number of CVD admissions registered for this group than for the younger age group (5-65 year-olds) despite the older group being a smaller sub-population.

In this study, particulate air pollutant PM_{10} and NO_2 were found to have consistent short-term effects on both respiratory and cardiovascular hospital admissions throughout the monitoring period although there was seasonal variation in their monitored levels. Meanwhile SO_2 was only positively associated with the number of respiratory admissions and O_3 did not have any effect on either respiratory or cardiovascular admissions in this study.

The associations of PM_{10} with respiratory and CVD admissions found in this study were consistent with previous studies. A recent study in New Mexico, US has found strong effects of PM_{10} for respiratory and CVD emergency room visits with estimated increases of 3.2% (95% CI: 0.5–6.0) for respiratory emergency room visitsand 3.1% (95% CI: −0.5 to 6.8) for cardiovascular emergency room visits (Rodopoulou et al., 2014). Another study in Seoul, Korea also reported that a 10 $\mu g/m^3$ increase in PM_{10} was associated with increases of 0.77% (95% CI: 0.53-1.01) in hospitalization for cardiovascular causes and 1.19% (95% CI: 0.94-1.44) for respiratory causes (Yi et al., 2010). These results again demonstrate that particulate matter can negatively impact population health although PM_{10} sometimes is considered only as a surrogate parameter for the impact of fine particles ($PM_{2.5}$) (Wilson and Suh, 1997).

The association between PM_{10} pollution and respiratory hospital admissions including the severity of respiratory disease was reported as early as in the 1980s (Pope, 1991). Many other following studies across the globe have found similar results (e.g. in Hong Kong (Wong et al., 1999), the US (Schwartz, 1995), and Europe (Le Tertre et al., 2002). There is also an extremely large epidemiologic literature that provides evidence that exposure to PM contributes to CVD. The most recent review by Franklin et al. (Franklin et al., 2015) reported that many daily time-series, case-crossover, and related studies have demonstrated that short-term (one or a few days) changes in PM are associated with cardiovascular hospitalizations, fatal and nonfatal ischemic heart disease events, heart failure, and ischemic stroke. Meanwhile epidemiological studies of long-term exposure to PM (years to decades) indicate even larger cardiovascular health consequences with many studies (e.g. Brook et al., 2010 or Pope and Dockery, 2006) indicating that reductions in PM pollution contribute to improvements in cardiovascular and overall health.

For cities in low-income countries, air pollution is now considered a new respiratory risk which requires systems for measuring pollution levels and epidemiological surveillance to be put in place rapidly in order to prevent the health risks of air pollution (Nejjari et al., 2003). In this study, the average value of PM_{10} was 74.0 µg/m^3, which was relatively high (higher than the current WHO guideline) and higher than those in other studies in Asia: for example 65.06 µg/m^3 in Korea, 2000-2006 (Yi et al., 2010), 52.1 µg/m^3 in Bangkok, 1999–2003 (Vichit-Vadakan et al., 2008); and 50.1 µg/m^3 in Hong Kong, 1994–1995 (Wong et al., 1999),. although still lower than the levels recorded in different studies in cities across China with PM_{10} concentrations of 75 up to 140 µg/m^3 (Lu et al., 2015). The increases in risk for respiratory and CVD admissions due to increases in PM_{10} found in this study were in the range reported in previous studies. It is noted that there was not any relationship between the mean level of PM_{10} and the increases in risks of respiratory and CVD admission among studies in China although such relationship could be established for daily mean PM_{10} level and mortality data in those studies (Lu et al., 2015).

We found that changes in NO_2 level were more strongly associated with respiratory and CVD hospital admissions than changes of PM_{10}. This phenomenon has been reported previously in several studies across the globe (Burnett et al., 1999; Chen et al., 2010; Fusco et al., 2001). The importance of NO_2 as a cause of increased hospital admissions is not sufficiently understood

(Chang et al., 2005) although NO_2 is considered as a key precursor for a range of secondary pollutants. With more development expected in HCMC grows, the city's growing vehicle fleet will surely contribute to an increase in NO_2 pollution in HCMC and thus this air quality parameter should be monitored carefully so as to inform public health policy of the city.

The results for SO_2 and O_3 were also comparable to previous studies. Atkinson et al. (1999) found significant positive associations between emergency hospital admissions for respiratory disease and PM_{10} and SO_2, but no association for O_3. The results were seen as not significantly different from earlier results from London and were comparable with those determined in North America and Europe (Atkinson et al., 1999). But it is recognised that the evidence of the effect of SO_2 and O_3 on hospital admission has not been well documented and is inconclusive. For example, Chen et al. (2010) and Chang et al. (2005) both found that SO_2 was associated with CVD admissions while it was non-significant in this study. Chang et al. (2005) also reported that higher levels of O_3 were positively associated with increases in the daily number of CVD hospitalizations but noted that little information about the effects of O_3 on hospital admissions is available.

Findings of this study that will probably have an impact on public health policy since the risks of air pollution on respiratory diseases are probably equal for the adult group and the elderly while the elderly group would require special attention when it comes to CVD risk from air pollution. Anderson et al. (2003) has tried to address this question earlier and found that there is a steep increase in attributable risk with age regarding CVD, reflecting the dominant influence of baseline risks. The attributable risk for cardiovascular disease in the elderly is considerably greater than for respiratory disease, due to the higher baseline admission rates. Therefore, any air pollution abatement policy will provide more benefit to the elderly group who already have high risks of CVD admission.

We acknowledge that there are limitations in this study including the inherent limitation of exposure assessment using ambient air monitoring stations. The effect of exposures to indoor air in residences could not be assessed. Smoking is an important source of air pollution in HCMC but its effect could not be assessed in this study. And finally, the small sample size for seasonal cause-specific admissions limited our power to analyse the seasonal effects.

5. Conclusion

This study has confirmed that air pollutants (PM_{10}, NO_2, SO_2) were positively associated with daily hospital admission for respiratory and CVD diseases of the population in HCMC. PM_{10}, NO_2 were significantly associated with hospital admissions for both respiratory and CVD at lag 0 day; whereas SO2 was moderately associated with respiratory and CVD hospital admissions and O_3 was not associated with any of them. The risk of respiratory admissions increased from 0.7% to 2% while risk of CVD increased from 0.5% to 4% corresponding to 10 $\mu g/m^3$ increase in each air pollutant. Females were found to be more sensitive to exposure to air pollutants than males in regard to respiratory diseases but males had a higher risk of cardiovascular admissions than females in regard to exposure to PM_{10}. People aged 5-65 year-olds had a slightly higher risk of respiratory admissions but a smaller risk of cardiovascular admission caused by air pollutants than the elderly. NO_2 was found to have the strongest impact on respiratory and CVD admissions. A prevention program to reduce exposure to air pollutants and their adverse health effects should be developed to protect HCMC residents.

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