



## Air pollution and risk of respiratory and cardiovascular hospitalizations in the most populous city in Vietnam



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### HIGHLIGHTS

- Ho Chi Minh City, Vietnam was vulnerable to high level of air pollution.
- NO<sub>2</sub> and PM<sub>10</sub> were significantly associated with cardiorespiratory hospitalizations.
- SO<sub>2</sub> and O<sub>3</sub> had inconsistent effects on cardiorespiratory hospitalizations.
- Elderly people were more sensitive to cardiovascular risk of air pollution than others.
- A prevention program that reduces health risk caused by air pollution is recommended.

### GRAPHICAL ABSTRACT



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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<sub>10</sub>, NO<sub>2</sub>, SO<sub>2</sub>, and O<sub>3</sub> 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<sub>10</sub>, NO<sub>2</sub>, SO<sub>2</sub>, O<sub>3</sub> 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<sub>2</sub> and PM<sub>10</sub> were strongly associated with hospital admissions for both respiratory and cardiovascular diseases (CVD); whereas levels of SO<sub>2</sub> were only moderately associated with respiratory and CVD hospital admissions and O<sub>3</sub> concentration was not associated with any of them. For a 10 µg/m<sup>3</sup> increase of each air pollutant, the risk of respiratory admissions increased from 0.7% to 8% 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 CVD, females (RR, 1.04, 95% CI, 1.01–1.07) had a slightly higher risk of admissions than males (RR, 1.03, 95% CI, 1–1.06) to exposure to NO<sub>2</sub>. 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<sub>10</sub>. People in the age group of 5–65 year-olds had a slightly higher risk of admissions caused by air pollutants than the elderly

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(65+ years old) except for a significant effect of PM<sub>10</sub> on the risk of cardiovascular admissions was found for the elderly only.

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## 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<sub>2</sub>), sulphur dioxide (SO<sub>2</sub>), and ozone (O<sub>3</sub>) 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<sub>x</sub>, 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 < 10 μm (PM<sub>10</sub>), NO<sub>2</sub>, SO<sub>2</sub>, and O<sub>3</sub> 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<sup>2</sup> 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<sup>2</sup> (Huyen, 2012). HCMC has two seasons: the rainy season (May–November) and the dry season (December–April). The city experiences 2400–2700 h 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

#### 2.2.1. 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<sub>10</sub>, SO<sub>2</sub>, NO<sub>2</sub> and O<sub>3</sub>. The location of the four monitoring stations is shown in Fig 1.

Daily, city-level exposure estimates of PM<sub>10</sub>, NO<sub>2</sub>, SO<sub>2</sub> and O<sub>3</sub> (maximum 8-h moving average) were generated using hourly data from the above monitoring stations.

A 75% completeness criterion was applied in aggregate data calculation. Thus, if < 18 h of PM<sub>10</sub>, NO<sub>2</sub> and SO<sub>2</sub> concentration data were available in a day then the daily average concentration for the day was considered as 'missing' data. For O<sub>3</sub>, if < 6 h 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<sub>3</sub>, 7% for NO<sub>2</sub>, 14% for PM<sub>10</sub> and 26% for SO<sub>2</sub>). 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°39'59.75 East; latitude, 10°47'47.48 North), and comprised daily minimum, maximum, and average temperatures (°C) and minimum, maximum and average relative humidity (%).

#### 2.2.2. 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

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