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The association between particulate air pollution and respiratory admissions among young children in Hanoi, Vietnam

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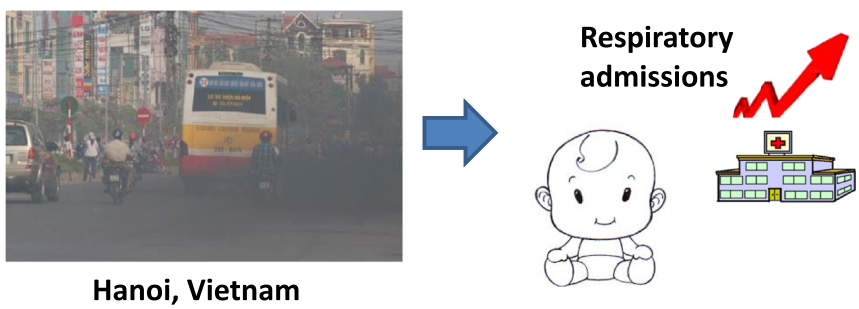
HIGHLIGHTS

- First study on human health impact of air pollution in the north of Vietnam
- Elevated levels of PM_{10}, $PM_{2.5}$ or PM_1 were associated with respiratory admissions.
- The smaller PM could have stronger impact on children respiratory admission.
- Urgent intervention measures are needed to control air pollution in Vietnam.

GRAPHICAL ABSTRACT



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ABSTRACT

While the effects of ambient air pollution on health have been studied extensively in many developed countries, few studies have been conducted in Vietnam, where the population is exposed to high levels of airborne particulate matter. The aim of our study was to examine the short-term effects of PM_{10}, $PM_{2.5}$, and PM_1 on respiratory admissions among young children in Hanoi. Data on daily admissions from the Vietnam National Hospital of Paediatrics and daily records of PM_{10}, $PM_{2.5}$, PM_1 and other confounding factors as NO_2, SO_2, CO, O_3 and temperature were collected from September 2010 to September 2011. A time-stratified case-crossover design with individual lag model was applied to evaluate the associations between particulate air pollution and respiratory admissions. Significant effects on daily hospital admissions for respiratory disease were found for PM_{10}, $PM_{2.5}$ and PM_1. An increase in 10 $\mu g/m^3$ of PM_{10}, $PM_{2.5}$ or PM_1 was associated with an increase in risk of admission of 1.4%, 2.2% or 2.5% on the same day of exposure, respectively. No significant difference between the effects on males and females was found in the study. The study demonstrated that infants and young children in Hanoi are at increased risk of respiratory admissions due to the high level of airborne particles in the city's ambient air.

1. Introduction

Over the past decades, numerous epidemiologic studies have reported increases in human mortality and morbidity associated with exposure to ambient air pollution. Among air pollutants, atmospheric

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particles have multiple effects on human health and have been studied extensively. Respirable particles or particulate matter (PM) of concern include "inhalable coarse particles" with an aerodynamic diameter <10 μm (PM_{10}) and "fine particles" with an aerodynamic diameter <2.5 μm ($PM_{2.5}$) and 1 μm (PM_1), respectively (Kim et al., 2015). Particulate matter originates from a wide range of sources including both natural and anthropogenic, such as volcanoes, dust storms, forest fires, sea spray, solid-fuel combustion, industrial and agriculture activities, erosion of the pavement by road traffic and abrasion of brakes and tyres (Atkinson et al., 2010; Srimuruganandam and Shiva Nagendra, 2012). For example, vehicle exhaust or secondary aerosols are the main source of PM_1 while particles created by abrasion of brakes are mostly categorized as $PM_{2.5}$ and those generated by the road/tyre wear are found in the coarse range ($PM_{10-2.5}$) (Manoli et al., 2002; Wåhlin et al., 2006). PM_{10}, $PM_{2.5}$ and PM_1 have been reported to cause a variety of adverse health effects such as increasing the risk of acute respiratory illnesses requiring emergency department attendance or hospital admission and increasing mortality (Barnett et al., 2005; Franck et al., 2015; Hua et al., 2014; Kloog et al., 2014; Mehta et al., 2013; Peel et al., 2005; Phung et al., 2016; Qiu et al., 2014; Sousa et al., 2012; Stafoggia et al., 2013; Yang et al., 2015). For example, the study by Sousa et al. (2012) found that an increase in 10 μg/m^3 of PM_{10} was associated with an increase of 2% in risk of respiratory admission. Similarly, Kloog et al. (2014) showed that exposure to each 10 μg/m^3 increase in $PM_{2.5}$ was associated with 2.2% increase in hospital admission for respiratory disease. In its air quality guideline, the WHO recommended the daily level of PM_{10} and $PM_{2.5}$ should not exceed 50 and 25 μg/m^3, respectively (WHO, 2005).

Children are more vulnerable to the adverse health effects of air pollutants than adults because their defence mechanisms are still developing and they inhale a larger volume of air per body weight (Bearer, 1995; Salvi, 2007). There is an increasing amount of evidence about the role of atmospheric particles in the initiation, progression and exacerbation of childhood respiratory diseases such as pneumonia, acute bronchitis and asthma (Barnett et al., 2005; Magas et al., 2007; Tolbert et al., 2000).

While the effects of ambient air pollution on health have been studied extensively in many countries, especially in developed countries, only two studies have been conducted in Vietnam to date and both were in Ho Chi Minh City. Mehta et al. (2013) assessed the effects of exposures to PM_{10} and other pollutants such as NO_2, SO_2 and O_3 on hospitalization for Acute Lower Respiratory Infections (ALRI) among children aged <5 years. In that study, PM_{10} was associated with increased admission for ALRI in the dry season but its effects could not be distinguished from that of NO_2 due to their high correlation. The other study found that the risk of respiratory admission (for all ages) increased by 0.7% for each 10 μg/m^3 increase in PM_{10} (Phung et al., 2016). The health effects of $PM_{2.5}$ and PM_1 were not examined in those studies.

Hanoi is the capital and second largest city in Vietnam. In recent decades, Hanoi has faced several environmental pollution issues including serious air pollution. As reported in the National State of Environment Report on Air quality (MONRE, 2014), during the period 2010–2013, the air quality on 40–60% of monitored days in Hanoi was unhealthy (Air quality index AQI = 101–200), with several days at very unhealthy (AQI = 201–300) or hazardous (AQI > 300) levels. During 2010 and 2011 there were 188 days (25%) in which the PM_{10} level was above the national standard of 150 μg/m^3 and 425 days (60%) in which the $PM_{2.5}$ level was above the national standard of 50 μg/m^3. Air pollution in Hanoi is caused by a combination of factors including a high number of vehicles using limited road infrastructure; large-scale development activities including construction of roads, houses/buildings; and other industrial activities around Hanoi. In addition, the practices of stubble burning after crop harvest in the suburbs of Hanoi and of using kerosene and coal for cooking are also sources of particulate matters and other air pollutants contributing to the seriousness of air pollution and harm to public health (MONRE, 2014).

This study aimed to examine the short-term effects of the high level of particulate air pollution (PM_{10}, $PM_{2.5}$, and PM_1) in Hanoi on the risk of respiratory admission among young children in this city.

2. Methods

2.1. Research location

The study was conducted in Hanoi with a population of approximately seven million and a population density of 2031 residents per square kilometre (GSO, 2011).

2.2. Data collection

2.2.1. Hospital admissions

Data on hospital admissions for respiratory disease (respiratory admissions) were obtained from the Vietnam National Hospital of Paediatrics, the largest paediatric hospital in Hanoi, from September 2010 to September 2011. Information available for each admission for respiratory disease comprised of date of birth, sex, date of admission, date of discharge, and ICD-10 code (J00-99). All admitted cases aged 28 days-5 years old were residents of Hanoi.

2.2.2. Air pollutants and weather conditions

Air quality data were collected from the Centre for Environmental Monitoring Portal (Vietnam Environment Administration). The data were recorded from a national automatic air quality monitoring station in Hanoi which is about 10 km away from the Vietnam National Hospital of Paediatrics. Air quality data included hourly average temperature (°C) and hourly average value of air pollutant concentrations (μg/m^3) including PM_{10}, $PM_{2.5}$, PM_1, nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO), and ozone (O_3) from September 2010 to September 2011. Daily average temperature and daily average concentration of air pollutants were calculated from hourly values of temperature, PM_{10}, $PM_{2.5}$, PM_1, NO_2, SO_2 and the maximum 8 h moving averages were generated for CO, O_3.

A 75% completeness criterion was applied to daily aggregate data calculation, meaning that if <18 h of temperature, PM_{10}, $PM_{2.5}$, PM_1, NO_2 and SO_2 concentration data were available in a day then the daily average concentration for the day was assigned as 'missing' data. For CO and O_3, if <6 h of concentration data were available then the 8-hour daily maximum concentration for the day was assigned as 'missing.' Such "missing" values accounted for <3% of all observations during the studied period (<1% for temperature, 1.5% for SO_2 and ~3% for PM_{10}, $PM_{2.5}$, PM_1 and NO_2) of total 366 days. All missing values were replaced with the mean of one datum before the missing value and one datum after the missing value using the mean-before-after method (Norazian et al., 2008).

2.3. Data analysis

A time-stratified case-crossover design was used in this study to examine the relationship between particulate air pollution and hospital admissions for respiratory diseases. In the case-crossover design, the exposure levels (cases) for a given day of the week when a health event occurred was compared to the exposure levels of the same days in nearby weeks (controls), to examine the differences in exposures which could be used to explain the differences in daily number of admissions. In our study, the cases and controls were matched by the same days of one week before and after to control any weekly patterns in hospital admissions and pollution levels. The length of the time strata was 21 days, so each case had two matching control days.

A health event may occur after a person has been exposed to the air pollutants on the same day or on several subsequent days. To explore the delayed effect of exposure to air pollution on hospital admissions for respiratory diseases, we added individual lag variables of PM at