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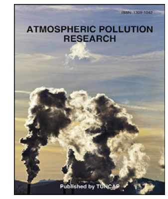

Original article

Evaluation of the relationship between allergic diseases in school children at Seoul's roadside elementary schools and air pollution

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A B S T R A C T

An elementary school is an important public place for children and it is where they spend most of their days. The objective of this study was to survey the environmental conditions at schools and to assess the relationship between air pollution and allergic diseases using the International Study of Asthma and Allergies in Childhood questionnaire. Nine elementary schools were selected and subsequently classified into three groups. The selection included two schools with no traffic-related or other pollutants, four schools situated near roads with six lanes, and three schools situated near beltways. Allergic diseases were assessed in a total of 6301 students. School zones with critical exposure to pollutants were selected within each school and were evaluated based on the levels of particulate matter, fine particulate matter, ozone, carbon monoxide, carbon dioxide, nitrogen dioxide, sulfur dioxide and black carbon. O_3 and PM_{10} exposures were significantly associated with the prevalence of lifetime symptoms and diagnosis of asthma. O_3 and PM_{10} exposures were also associated with lifetime symptoms, diagnosis, and 1-year physician diagnosis prevalence of allergic rhinitis. BC exposure was significantly associated with the rates of 1-year treatment of disease for allergic rhinitis. For schools located near sources of air pollution, the prevalence of lifetime symptoms for atopic dermatitis was significantly increased. Some symptoms of allergies were significantly increased at schools surrounded by a higher traffic volume. This study provides additional evidence that exposure to school zone air pollutants and traffic volume put school children at risk for childhood allergic diseases. Thus, strategies and actions are necessary to protect children in schools from exposure to environmental pollutants. In addition, future analysis to evaluate the relationship between traffic-related air pollution and the development of allergic diseases at more advanced ages are needed to confirm or refute these associations.

1. Introduction

Allergic diseases have rapidly increased worldwide in the 20th century due to various factors, including fast-food diets, changes in lifestyle, exposure to new allergic antigens from increased indoor living, and air pollution (Asher, 2010). According to the World Health Organization (WHO), 20% of the global population suffers from asthma, allergic rhinitis, atopic dermatitis, or allergic conjunctivitis. In particular, approximately 150 million people are estimated to be afflicted with asthma, which is recognized as a

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major cause of chronic conditions in children (WHO, 2003). However, the cause and origin of allergic diseases remain largely unknown. Previous studies have found associations between allergic diseases and viral infections, passive smoking, genetic factors, gender, race, socio-economic standards, dietary lifestyle, and exposure to air pollutants. In addition, because people spend more time indoors, they are exposed to more indoor antigens, which in turn increase the occurrence of asthma and respiratory allergic diseases (Brauer et al., 2007; Cheng et al., 2013). With heightened interest in the effect of air pollution on health, recent studies have shown that traffic-related pollution influences not only respiratory diseases, such as asthma, but also impact sensitization to allergic antigens and the occurrence of allergic diseases (Jonathan et al., 2012). In particular, children are exposed to a higher concentration of pollutants because they inhale more air than adults despite their small lung size (Gruzieva et al., 2013; Vette et al., 2013). Furthermore, children are more vulnerable to such exposure because their lungs and defense mechanism are underdeveloped (Chiu et al., 2013).

Air pollutants related to road traffic include particulate matter (PM_{10}), fine particulate matter ($PM_{2.5}$), ozone (O_3), carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and diesel exhaust particles. With the increase in air pollutants due to higher traffic volumes in urban areas, they are being pointed out as a major risk factor for chronic respiratory or allergic diseases (McConnell et al., 2006). Many studies are therefore being conducted on air pollutants and the occurrence of allergic diseases (Asher, 2010; Santus et al., 2012; Gonzalez-Barcala et al., 2013). One recent study reported a correlation between black carbon (BC), an air pollutant emitted from vehicles, and the occurrence of allergic diseases (Patel et al., 2010; Spira-Cohen et al., 2011; Cheng et al., 2013). Given that BC represents an extensive range of harmful substances caused by incomplete combustion. It is being used as an indicator for diesel emissions in large cities. Furthermore, traffic-related pollution, including diesel gas emissions, is known as a major risk factor that triggers immune disorders among children (Fedulov et al., 2008; Vette et al., 2013).

This study focused on environmental factors as one of the causes of allergic diseases by investigating the effects of both air quality and road traffic-related factors on elementary school students at schools in urban areas. To analysis factors according to road traffic characteristics, we compared the prevalence of asthma, allergic rhinitis, and atopic dermatitis in schools located in urban residential neighborhoods, schools close to roads that have six or more lanes, and schools close to highways, such as beltways.

2. Methods

2.1. Study design and sampling methods

This is a cross-sectional study which categorized the characteristics of school areas with focus on the schools and the school zones in Seoul, and examined the relationship between the degree of environmental pollution and allergic disease. Seoul is a capital city of South Korea and is the political, economic, and cultural center with a population of about 10 million. In terms of pollutants, the assessment was conducted on the substances whose associations with allergic diseases had been examined in previous studies (Asher, 2010; Santus et al., 2012; Gonzalez-Barcala et al., 2013).

Our study nine elementary schools located in Seoul were selected and classified into three groups based on the characteristics of the roads in the surrounding area and the air quality: Group A consisted of two schools located in residential neighborhoods; Group B included four schools that had roads with more than six lanes within 50 m of the school entrance; and Group C included three schools that had a beltway or arterial road within 50 m of the school entrance (Fig. 1). Group B schools was located in the north of downtown in Seoul with a road with 4 or more lanes nearby, and has a cement plant, the east main street, a large-scale distribution center as major sources of pollution although the road in front of school has low traffic volume (Fig. 1b). Group C schools was located in downtown in Seoul, with a road with 4 or more lanes and a beltway in front of the school (noise barrier installed toward road), a bus stop at the front gate, and frequent traffic and vehicular idling nearby (Fig. 1c).

All of the selected schools were constructed more than five years ago. The questionnaire on allergic diseases was filled out for a total of 8623 students in grades 2nd to 6th. To analysis the environmental factors that affected the occurrence of allergic diseases among these elementary school students, this study largely classified factors into those related to air pollution and those associated with road traffic. To assess air pollution-related factors, measurements were carried out at the school zone in front of the front gate of the relevant elementary school. Previous studies measured the following air pollutants related to allergic diseases: PM_{10}, $PM_{2.5}$, O_3, CO, NO_2, SO_2, and BC (Raysoni et al., 2011; Kim et al., 2013). To assess road traffic, we determined the average number of cars that operated in the school zone in front of the school gate. Measurements were conducted at nine sites in the school zones for a total of 10 h (07:30–17:30) per site between June and September in 2011 and 2012 (excluding summer vacation). PM_{10}, $PM_{2.5}$, O_3, CO, SO_2, NO_2, O_3, and BC (average of one reading per minute) were measured at one site on the road around the front gate in each school. The sampling periods in the school zone were two days (one site/day) per school.

The method to measure for PM_{10} was the β-ray absorption method (TAPI, Beta-Attenuation Mass Monitor, Model BAM1020) which traps particulate matters less than 10 μm that are floating in the atmosphere on filter paper for 10 h, pass β-ray through it and calculate weight concentration of particulate matter successively. The method to measure SO_2 was the UV fluorescence method (TAPI, UV Fluorescence Analyzer, Model 100E) was which measures sulfur dioxide concentration in the sample atmosphere using the intensity of fluorescent light emitted from sulfur dioxide excited by short-wavelength of ultraviolet light. The method to measure NO_2 (TAPI, Chemiluminescence Analyzer, Model 200E) was chemiluminescence assay which converts nitrogen dioxide into nitric oxide with a converter and measures nitric oxide concentration in the sample atmosphere, using the fact that chemiluminescence generated when NO_2 is generated by the reaction with ozone is proportional to nitric oxide concentration. The method to measure CO was the non-dispersive infrared spectrometry which measures carbon monoxide in the atmosphere with a non-dispersive type infrared gas analyzer using optical absorption of carbon monoxide in the infrared region. The method to measure of O_3 (TAPI, UV Absorption Analyzer, Model 400E) was the UV absorption method which measures ozone concentration in the atmosphere successively by measuring the change in UV absorption in the vicinity of 254 nm wavelength. The method to measure BC concentration used portable aethalometer (model AE42-7-ER-MC, Magee Scientific) that converts the degree in which the lights in the seven wavelengths (370, 470, 520, 590, 660, 880, 950 nm) is attenuated by particles collected by the quartz filter into mass concentration by wavelength. A single wavelength infrared light (880 nm) of known intensity is directed onto the collection area (Kim et al., 2013).

In order to assess the contribution of traffic pollutants, we conducted a survey of traffic volume by vehicle type. In the case of average traffic volume in school zones, we investigated the proportion of the traffic volume during 12 h (around 8:00 a.m