ASSESSMENT OF INDOOR AND OUTDOOR AIR QUALITY AT ELEMENTARY SCHOOLS IN HANOI

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Abstract

Indoor Air Quality (IAQ) is becoming an interesting topic for scientists, especially for schools where the objectives are children with their sensitivity with air quality components. This study focus is the air quality inside class rooms at some elementary schools (ELS) of Hanoi with representative parameters including $PM_{2.5}$, PM_{10}, CO_2, NO_2, and VOCs. Simultaneously, those parameter concentrations in school yards are also monitored to provide data for comparison and evidence of the existence of pollutants indoor. The results indicated that the main air quality issues in schools is particulate matters, particularly $PM_{2.5}$, in which some traffic-nearby schools having concentrations of 2 - 3 times higher than standards. VOCs concentrations are high indoor and in yards of schools located near markets and traffic roads. CO_2 and NO_2 indoor concentrations are below standards in all schools. ELS-7 ELS is the air pollution hot spot where most of indoor and in yards concentrations are the highest values. Two significant factors effecting air quality of schools are traffic and activities of residential people living around them.

Keywords: Air pollution, Indoor air quality, School, Hanoi

1. Introduction

Most of people are being aware about the impacts of ambient air pollution to the landscape, bio-system, and human lives. However, not many people get to know that indoor air pollution (IAP) could also have similar impacts to its objectives. *Indoor* here could be understood that the object has a boundary with very limited direct ventilation with the surrounding environment. The ventilation could be done mostly by indirect air exchange by manmade facilities such as fan and air conditioner. Some example of the indoor environment could be named as houses, offices, classrooms, commercial building, stations, multi-purpose building, and car, bus, subway inner, etc. [1, 12, 13, 9]. As statistic data, one could spend 87% of time living inside closed building and 6% inside closed vehicles [7]. As a result, people are now living in indoor environment in long time and it could become a risk if IAQ is not ensured in safe level [7, 1]. There are many sources of IAP in any home. These include combustion sources such as oil, gas, kerosene, coal, wood, and tobacco products; building materials and furnishings as diverse as deteriorated, asbestos-containing insulation, wet or damp carpet, and cabinetry or furniture made of certain pressed wood products; products for household cleaning and maintenance, personal care, or hobbies; central heating and cooling systems and humidification devices; and outdoor sources such as radon, pesticides, and outdoor air pollution [7, 1, 12, 13, 10, 9]. IAP could have significant impacts to human health including direct and acute impacts (*e.g.* eye, nose, throat allergy, headache, dizzy and other tired symptoms) as well as other indirect and chronic impacts (*e.g.* respiratory diseases, cancer or serious asthenia or death) [2]. World Health Organization (WHO) reported

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noticeable figures of the estimation of mortality caused by outdoor environment (3.7 mil. people) and indoor environment (4.3 mil. people) [3]. Indoor related mortality are found in low income countries where there is a significant use of pollution containing energy sources [7, 1, 12, 13, 10, 9, 2, 3].

Studies on environmental quality, in general, and air quality, in particular of the big cities showed that their environment is alarming. Air pollution index of Hanoi city is high, especially PM with concentrations of 1 - 2 times higher than Vietnam National Ambient Air Quality Standards (VN AAQS) [5]. The PM concentrations at some traffic conjunctions and construction sites are 5 - 6 times higher than VN AAQS [4]. Washington State Department of Health gave a warning that indoor pollutants could be far exceeding outdoor pollutants. Some indoor pollutants are having increasing trends in terms of concentration, including: formaldehyde (HCHO), volatile organic compounds (VOCs), radon, fungi and bacteria, by-products of combustion as carbon monoxide (CO), nitrogen oxides (NO_x) and particulate matters (PM) [12]. IAP might be a source of increasing of students' eye and skin diseases, decreasing of teachers' productivity, and degradation of studying environment [12]. Since there is no production process, the main sources of air pollution in classes are from construction materials, furniture and the lack of ventilation [8, 6].

In this study, concentrations of some typical pollutants ($PM_{2.5}$, PM_{10}, VOCs, CO_2, NO_2) of both indoor and in the yards are monitored in ten ELS of Hanoi. The monitoring data is used for comparison of pollution of different sites and as an evidence for IAP in school class rooms.

2. Methodology

The yards in 10 ELS of Hanoi where surrounding contexts were relatively different (Table 1). A Q-TRAK (TSI, model 8552) was used for CO_2 measurement. A PpbRAE parts per billion Volatile Organic Compound Monitor (Model PGM-7240) was used for VOCs measurements. Indoor and outdoor PM_{10}, $PM_{2.5}$ levels were measured using a TSI DUSTTRAK™ Aerosol Monitor Model 8520. The NO_2 was measurement by NO_x Monitor Model 405 nm. To determine the SO_2 concentration, Tedlar air sampling bags and a portable sampling pump (Airchek sampler, model 224- 43XR) at 1 ml/min were used for grab air samples. The air bags were then transferred to the laboratory for analysis by a Thermo Electron (model 43B) Pulsed Fluorescence SO_2 Analyser.

Table 1. List of chosen ELS for the study in Hanoi

ELS name	Location characteristics
ELS-1	Near the roads of central city with relatively low intensity of traffic
ELS-2	Inside a residential area of central city
ELS-3	Inside a residential area, with a distance to city center
ELS-4	Near the roads of central city with high traffic intensity and crowded commercial activities
ELS-5	Near the main road of central city with high traffic intensity
ELS-6	Near the roads of central city with high traffic intensity and crowded commercial activities
ELS-7	Near the roads of central city with high traffic intensity and crowded commercial activities
ELS-8	Inside a residential area of central city
ELS-9	Near the roads of a newly developed area
ELS-10	Near the roads with relatively low intensity of traffic, with a distance to city center

3. Results and discussions

3.1. Concentration of particulate matter

The highest levels of $PM_{2.5}$ and PM_{10} indoor are 173 µg/m^3 and 188.3 µg/m^3 at ELS-1 and ELS-8, respectively. While the highest levels of $PM_{2.5}$ and PM_{10} outdoor are 354.6 µg/m^3 and 409.5 µg/m^3 monitored at ELS-7, respectively. Fine particles ($PM_{2.5}$), coarse particles (PM_{10}) in classrooms and in the yards of study sites are correlated (Fig.1). It should be noted that indoor $PM_{2.5}$ concentrations of all sites are over standard; however, PM_{10} concentrations are lower in all cases. PM_{10} of some sites as ELS-1, ELS-4, ELS-8, ELS-10 are slightly higher than standards. Schools in residential areas (ELS-2, ELS-3) have a lower PM concentrations than schools being located near the roads. The schools located near high traffic intensity have PM concentrations of 2-3 times higher than standard and in some cases, there are additional impacts from commercial and production activities. Fine particles concentrations indoor might be higher than outdoor, e.g. at ELS-8 and ELS-9 sites. The reasons for this might be variety, for instance, there is some movement of students in break time which makes particles emitted and dispersed in the air, especially fine particles. There was a significant high concentration of PM, both of $PM_{2.5}$ and PM_{10}, in the yard of ELS-7 which was noted as the contribution of a construction works of nearby residential areas.

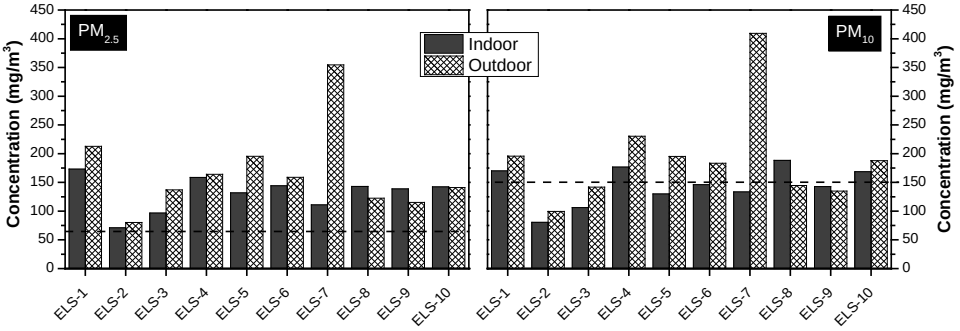

Fig. 1. Indoor and outdoor levels of $PM_{2.5}$, PM_{10} at schools; Dash lines (---) are IAS of $PM_{2.5}$ (65 µg/m^3) and PM_{10} (150 µg/m^3) [1].

3.2. Concentration of CO_2, NO_2

CO_2 and NO_2 concentrations are lower than standards at all study sites. CO_2 concentrations are relatively homogeneous in all school yards. Indoor CO_2 concentrations are always higher than outdoor in all data sets (Fig. 2). The highest levels of CO_2 indoor and outdoor are 727.7 ppm and 427.6 ppm at ELS-7 ELS, respectively. Respiratory phenomenon is the most possible reason for these distinguished values. In contrast, NO_2 concentration of indoor is lower than outdoor due to its emitted sources as from anthropogenic activities, especially from the use of vehicles (Fig. 2). The highest levels of NO_2 indoor and outdoor are 66.6 µg/m^3 and 97.7 µg/m^3 at ELS-6 and ELS-7, respectively. ELS-5, ELS-6 and ELS-7 ELS have the highest concentration of NO_2 and the most convincing reason is that they are located close to the roads with high traffic intensity.

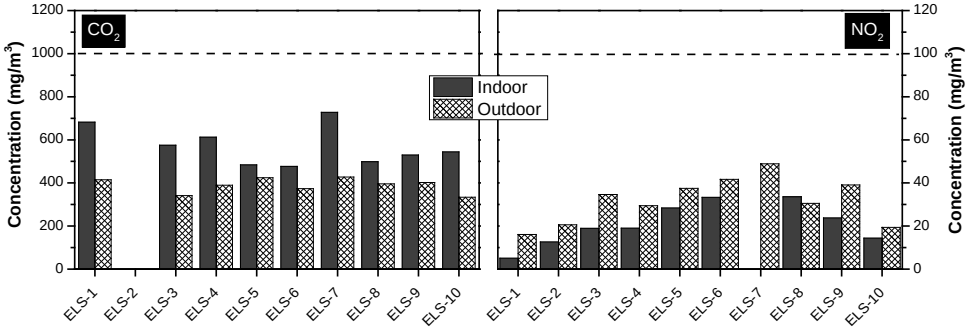

Fig. 2. Indoor and outdor concentration of CO_2, NO_2 at schools; Dash lines (---) are IAS of CO_2 (1000 ppm) [11] and NO_2 (100 µg/m^3) [1].

3. Concentration of VOCs

The highest levels of VOCs indoor and outdoor are 330 ppb and 925.2 ppb at ELS-7 and ELS-9 ELS, respectively (Fig. 3). High indoor and outdoor concentrations of VOCs were found in schools located near commercial areas. ELS-4, ELS-6, ELS-7 ELS as well as a school of a newly developed area, ELS-9 ELS were monitored a relatively high VOCs level. The source of the VOCs might be from different types of products or production process, in addition to VOCs from traffic. Indoor VOCs concentrations of these schools were higher than IAS of Hongkong. The rest of sites are having VOCs levels less than standards. It should be noted that indoor VOCs of some sites ELS-1, ELS-3, ELS-8 are higher than outdoor. It could be explained by the use of detergent for cleaning before monitoring time.

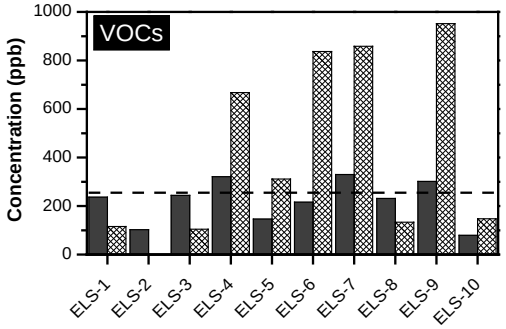

Fig. 3. Indoor and outdor concentration of VOCs at schools; Dash line (---) shows Hongkong IAS of VOCs (261 ppb) [8].

Conclusions

Air pollution study in 10-ELS in Hanoi indicates that the major problem is of fine particles, especially $PM_{2.5}$. The highest levels of $PM_{2.5}$ and PM_{10} indoor are 173 µg/m^3 and 188.3 µg/m^3 at ELS-1 and ELS-8 ELS, respectively. While the highest levels of $PM_{2.5}$ and PM_{10} outdoor are 354.6 µg/m^3 and 409.5 µg/m^3 monitored at ELS-7 ELS, respectively. The highest levels of CO_2 indoor and outdoor are 727.7 ppm and 427.6 ppm at ELS-7 ELS, respectively. The highest levels of NO_2 indoor and outdoor are 66.6 µg/m^3 and 97.7 µg/m^3 at ELS-6 and ELS-7 ELS, respectively. The highest levels of VOCs indoor and outdoor are 330 ppb and 925.2 ppb at ELS-7 and ELS-9 ELS, respectively. Hence, ELS-7 ELS is a hotspot of air pollution where both indoor and outdoor parameters are highest of all. Two of the most impact sources to IAQ are traffic intensity and residential activities of surrounding areas. Schools with less distance to the roads with more intensity are having more air pollutant concentrations indoor.

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