THE IMPORTANCE OF INDOOR AIR QUALITY STUDY IN SCHOOLS

ANDREA BRIGITA BLAGA[1]

[1] *"Babeş-Bolyai" University Cluj-Napca, Environmental Health Center Cluj-Napoca*

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Abstract: *Indoor air constitutes a wide variety of pollutants, exposure levels and different possible health outcomes. In schools, a good indoor air quality is essential to ensure a safe, healthy and comfortable environment for all the occupants, especially children, they being more exposed to indoor pollutants than adults due to their dynamic developmental physiology and immature set of systems. Consequently, in the latest studies, scarce attention has been given to indoor air quality in schools. The main pollutants investigated were the ones derived from fuel combustion, the subsequent emergence of new building materials, glues, paints, furniture, cleaning products and air fresheners; lately, volatile organic compounds caught researchers attention. Also, they concluded that heating, ventilation, and air conditioning, as well as surface cleaning comprise the fundamental operational strategies for adjusting the school environment to improve health and academic performance of students.*

INTRODUCTION

The indoor environment is a major source of human exposure to pollutants and some of them can have concentrations that are several times higher indoors than outdoors.(1)

While during the pioneering period of the research on indoor air quality, the main pollutants studied were the ones derived from the combustion of fuels, the subsequent emergence of new building materials, glues, paints, furniture, cleaning products and air fresheners droved the attention from particulate matter, nitrogen oxides and carbon monoxide to volatile organic compounds, in particular to formaldehyde known for its irritating effects on eyes, nose and respiratory tract. Indoor air quality (IAQ) in schools has been much less studied than IAQ in other buildings (e.g., offices and other working places). Consequently, scarce attention has been given to IAQ in schools related adverse health effects, and the effectiveness of remedial measures.(2)

Due to their dynamic physiological development, children are often more susceptible than adults to contaminants in air, water or food, which can lead to the overhelming of the child's immature organs and internal systems. Furthermore, the physiology of the developing child is continuously changing, differentiation, maturation and growth stages are known under the term of growth windows. These growth windows, considered to be critical windows of vulnerability and have no equivalent in adult physiology, create unique major risks for children exposed to various hazards, including the pollution mentioned earlier. The "Children are not small adults" principle is therefore sustained by various exposure, dynamic physiological development, higher life expectancy (compared to the one specific to the time of exposure) and the lack of political power.(3)

The present paper aims at reviewing recent studies regarding the importance of indoor air quality in schools, by highlighting the main pollutants found in the indoor environment, their sources, health effects and remedial measures.

Air quality in schools

Indoor air quality (IAQ) in schools is an important public health challenge. Particular attention should be paid to younger children, because they are more vulnerable to environmental contaminants exposure, including air pollution because they spend more time indoors.(2,4)

Sources of indoor air pollution with particles are mainly represented by heating systems (wood stoves), smoking, cleaning activities. Also, as a result of industrial activities, traffic or incomplete combustion, they can penetrate inside.(5) In 2004, Sundell has stated that "With regard to particles in indoor air, there is limited scientific knowledge with regard to their importance from a health point of view".

Since then, numerous studies have been focused on particles in indoor environments, including schools. Although the school environment normally lacks typical indoor particulate matter (PM) sources, such as smoking and cooking, there is growing evidence of high concentrations in classrooms.(6)

In 2015, Dorizas et al. (7) concluded that in some schools from Portugal, the PM10 concentrations exceeded the recommended limit values by more than 10 times for the majority of the cases. There were also many cases that the PM2.5 concentrations exceeded their limit values. PM concentrations were significantly affected by the ventilation rates and the presence of students. All of the measured particle sizes were greater during teaching than the non-teaching hours.

In school environments, children are constantly exposed to mixtures of airborne substances, derived from a variety of sources, both in the classroom and in the school surroundings (8) and the measured levels of exposure are for most of the cases greater than the recommended guideline values due to the intense presence of indoor pollution sources, even though the ventilation rates are in general satisfactory.(7)

Elevated concentrations of PM were mentioned inside the examined classrooms, as well as that of high levels of CO_2 exceeding 1000 ppm in relation to outdoor air. The

[1]Corresponding author: Andrea Brigita Blaga, Str. Busuiocului, Nr. 58, Cluj Napoca, România, E-mail: andreea.blaga@ehc.ro, Phone: +40744 806891
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characteristics of IAQ were significantly different, both in terms of classroom occupation (younger or older children) and of localization (urban or rural).(9,10) The measurements of airborne concentrations of total suspended particulates, respirable particulates, lead, asbestos, total volatile organic compounds and components, formaldehyde, and CO_2 in 17 Korean preschools showed that pollutants in indoor/outdoor and urban settings were higher than those in outdoor and rural areas, respectively.(4) The influence of outdoor air seemed to be determinant on carbon monoxide (CO), nitrogen dioxide (NO_2) and ozone (O_3) indoor concentrations, but the CH_2O and TVOC concentrations seemed to be related to internal sources, such as furniture and flooring finishing and cleaning products.(11,12) At specific cases, indoor concentrations during midday were 30%-40% higher than outdoor. Indoor ultrafine particles (N) concentrations were to some extent explained by outdoor N concentrations during school hours, together with average temperatures, related with natural ventilation.(13)

Schools near heavy traffic had a statistically significant mean average of CO and SO_2 ($P < 0.05$). The classrooms that had more than 35 students had higher and statistically significant averages of CO_2, SO_2, NO_2, and formaldehyde compared to classrooms that had fewer than 35 students ($P < 0.05$).(14)

The peak concentrations of formaldehyde and volatile organic compounds (VOC) registered (highest concentrations of 204 and 2320μgm^{-3} respectively) by Branco et al. (11), indicated the presence of specific indoor sources of these pollutants, namely materials emitting formaldehyde and products emitting VOC associated to cleaning and children's specific activities (like paints and glues). For formaldehyde, baseline constant concentrations along the day were also found in some of the studied rooms, which enhance the importance of detailing the study of children's short and long-term exposure to this indoor air pollutant.

Changing cleaning schedules and materials emitting formaldehyde, and more efficient ventilation while using products emitting VOC, with the correct amount and distribution of fresh air, would decrease children's exposure.(11,15)

Health effects of IAQ

Throughout history, man has known that polluted air may be detrimental to health (16) and prolonged exposure may lead to adverse biologic effects, even at low concentrations.(1) Among air pollutants, particulate matter (PM) is of the greatest interest mainly due to its acute and chronic effects on children's health.(9) Exposures in indoor environments and health effects due to such exposures vary between regions of the world. Poor air quality in schools has been associated significantly with a large spectrum of diseases and respiratory health is particularly challenged by air pollutants found in schools and absenteeism.(2,17)

The existing reviewed data emphasize the impact of IAQ parameters, namely, indoor temperature, ventilation rates, indoor concentration of carbon dioxide (CO_2), carbon monoxide (CO), particulate matters (PM), volatile organic compounds (VOCs), nitrogen dioxide (NO_2) and airborne microbes, on children's respiratory health. The most prevalent symptoms and respiratory diseases identified in the children are sneezing, rales, wheezing, rhinitis, and asthma. Other signs and symptoms, such as poor concentration, cough, headache, and irritation of mucous membranes, were identified.(1,10,17) Children living in households or studying in schools in urban areas are more likely to suffer from respiratory illnesses compared with children living in homes or studying in schools in rural areas.(1)

In Portugal elementary schools lack of concentration was associated with CO_2 concentrations above the maximum recommended level in indoor air ($p = 0.002$). There were no other significant associations.(10)

In one of their studies, Zhang et al. showed that at baseline, both indoor and outdoor SO_2 were found positively associated with prevalence of school-related symptoms. Indoor PM10 was found to be positively associated with new onset of skin, mucosal and general symptoms. CO_2 and RH were positively associated with new onset of mucosal, general and school-related symptoms.(18) Symptoms for SBS were commonly found in school children in Taiyuan City, China, and increased during the two-year follow-up period. Environmental pollution, including PM10, SO_2 and NO_2, could increase the prevalence and incidence of SBS and decrease the remission rate

Evaluating the risk of mixtures in the indoor air of school classrooms, Mishra et al. showed that in 92 % of the schools, indoor air mixtures belonged to the 'low concern' group, and therefore, they did not require any further assessment. In the remaining schools, toxicity was mainly governed by a single substance, with a very small number of schools having a multiple substance mix which required a combined risk assessment.(8)

The calculations of cancer risk from exposure to VOCs, and disease from exposure to PM2.5 (19), suggest the chronic health burden is relatively low for school buildings and the chronic health effects are driven primarily by PM2.5 exposures and secondarily by formaldehyde exposure.

Ventilation in schools

The ventilation in school buildings plays an important role in air quality. A higher air exchange may improve thermal comfort and air quality.(17)

The first Swedish professor in hygiene, Elias Heyman (1829–1889) at the Karolinska Institute, made an extensive study in Stockholm regarding schools with different ventilation systems, including measurements of CO_2. Heyman 1881 also studied homes and concluded that we cannot rely on "natural" ventilation if we want to live in "clean" air. At that time, the researchers stated that source control is a prerequisite for good hygiene. Thus ventilation was primarily a question of comfort and not of health.(16)

The carbon dioxide (CO_2) levels indicate ventilation conditions.(9) The concentrations of various pollutants, especially CO_2, its concentrations positively correlated to the number of students and negatively correlated to the ventilation rates (7) suggest the need for corrective interventions, such as reducing air pollutant sources and improving ventilation.(9,10) In addition, the changing of the ventilation timing can significantly reduce traffic-related pollutant concentrations in schools located near major roads.(20)

For both cancer and non-cancer effects, some evidence suggests that increasing ventilation alone is ineffective at reducing chronic health burdens. Other strategies, such as pollutant source control and the use of particle filtration, should also be considered.(19)

CONCLUSIONS

The level of increasing urbanization, sometimes even uncontrollable, continues to cause major impacts on human society. The effects of urban lifestyle on personal health do not resume only to the population from the cities, but expand with great velocity also to the communities with rural traditions. Population growth, overpopulation in certain areas and environmental pollution changed the spectrum of environment related diseases, not exclusively. To an equal extent, population growth and industrial development contribute to the degradation of the environment, which further affects children.

Indoor air is a dominant exposure for humans. The heating, ventilation, and air conditioning, as well as surface cleaning comprise the fundamental operational strategies for adjusting the school environment to improve health and academic performance of students.

The World Health Organization considers the achieved progresses small and a large number of challenges still remaining in spite of the increasing concern of the scientific community and educational and social sectors towards the relationship between the environment and children's health and development. In this context, the management of indoor air quality in schools must be maintained continuously in order to prevent and control acute and chronic diseases, especially those related to chemical and biological pollution.

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