



IMPACT OF CLIMATE CHANGE ON INDOOR AIR QUALITY AT SCHOOL

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Abstract

Climate change and urbanization demands have highlighted the importance of indoor air quality (IAQ) as a key component of healthy and sustainable buildings. School environments are of particular concern because children spend a significant portion of their day indoors and are more susceptible to the adverse effects of air pollution than adults. Numerous studies have linked poor IAQ in schools with respiratory diseases, allergic symptoms, reduced cognitive performance, and increased absenteeism.

This paper reviews current evidence on the health and educational impacts of indoor air pollution in schools and discusses opportunities for improvement through green building principles. Special attention is given to ventilation strategies, low-emission building materials, moisture control, air filtration systems, and the role of green infrastructure in reducing pollutant exposure. To illustrate local conditions, indoor air quality measurements were conducted in two primary schools in Niš, Serbia, revealing differences in pollutant presence associated with surrounding traffic intensity.

The findings emphasize the need for continuous IAQ monitoring and the integration of sustainable building solutions to create healthier, more resilient, and energy-efficient educational environments that support both student well-being and academic performance.

Key words: climate change, indoor air quality, school

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1. INTRODUCTION

One of the biggest environmental issues threatening human health in the world today is climate change and it poses significant risks to their right to good health. The World Health Organization states that climate change will cause approximately 250,000 additional deaths annually between 2030 and 2050 [1]. These deaths will primarily be caused by malnutrition, malaria, diarrhea, and heat stress. An estimated 3.6 billion individuals live in settings that are particularly susceptible to climate-related hazards. The adverse health effects of climate change are not distributed equally, with low-income nations and small island developing states bearing a disproportionate share of the burden despite their relatively minor contribution to global emissions. Evidence suggests that populations in highly vulnerable regions have experienced significantly higher mortality from extreme weather events, with death rates far exceeding those recorded in less vulnerable areas. Beyond its environmental consequences, climate change affects human health through complex interactions with social, economic, and healthcare systems, thereby influencing both population health outcomes and the resilience of public health infrastructure. In Europe, the spectrum of illnesses and diseases is changing, allergies increased and infectious diseases spread. Heat waves place a great strain in older people with cardiovascular and other chronic diseases.

Climate change can affect the indoor environment through heat and mass transfer between the indoors and outdoors through two fundamental ways. First, a direct response to global warming itself, with extreme weather phenomena such as frequent or violent hurricanes, leads to an increase in indoor air quality (IAQ) problems. Second, IAQ may be impacted by indirect actions taken to reduce emissions of greenhouse gases that can lead to increased concentrations of indoor air contaminants.

Most individuals in Westernized countries spend ~80% of their time indoors [2,3,4], demonstrating the importance of indoor air quality. The composition of indoor air is affected by several factors including outdoor pollutants, the quality/quantity of ventilation, indoor allergens, and activities such as smoking, heating, and cooking [5].

Indoor exposure to air pollutants can influence health, placing women and children in particular at risk of both acute and long-term ill health. Due to physiological characteristics children are more vulnerable to air pollutants than adults. They have higher ventilatory rates per minute (400mL/min/kg body weight in newborns compared to 150mL/min/kg in adults) and on that way increase risk of pulmonary exposure to respirable airborne particles, otherwise filtered in the upper airway. Also, a child aged 7-9 years typically exhales approximately 14 L of CO₂ per hour during normal breathing, whereas adolescents produce substantially higher amounts. Under conditions of moderate physical activity, a 15-year-old student may emit up to 85 L of CO₂ per hour [6]. Moreover, children inhale a larger fraction of air through their mouths than adults. This increased oral breathing allows pollutants to penetrate deep into the lower respiratory tract, which is more permeable. A higher cardiac pulse rate and the extent of tissue perfusion allow more rapid exposure to toxins absorbed into the blood. Although air pollution has long been thought to exacerbate minor acute illnesses in children, there is increasingly strong evidence that air pollution is associated with nontrivial increases



in infant mortality [7] and chronic disease in children [8]. Children's bodies and organs, including their lungs, are also still in development, which further increases risk [9]. Furthermore, children's developing immune systems are weaker than those of adults, strengthening the effects of pollution.

The aim of our study was to indicate the significance of indoor air quality monitoring, with special attention to children as risk population.

2. INDOOR AIR QUALITY IN SCHOOLS: HEALTH AND EDUCATIONAL IMPACT

Schools are among the most important indoor environments for children, as they spend a substantial proportion of their daily lives within classrooms. Classrooms are more crowded than most other workplaces, with roughly four times the occupancy density of typical office buildings [10]. Elevated indoor CO₂ concentrations can contribute to discomfort and reduced air quality in classrooms [11]. Prolonged exposure to indoor air pollutants during childhood has been associated with respiratory symptoms, allergic diseases, asthma exacerbations, impaired cognitive performance and increased school absenteeism. Consequently, ensuring adequate indoor air quality (IAQ) in schools is essential not only for protecting children's health, but also for supporting optimal learning conditions [12]. Numerous international studies have shown that school buildings frequently suffer from inadequate ventilation, poor maintenance, moisture-related problems and accumulation of biological and chemical pollutants [13]. The European Federation of Asthma and Allergy Associations has emphasized that poor IAQ in schools constitutes a widespread and preventable health risk, particularly for children with asthma and allergies, who are disproportionately affected by indoor environmental exposures [14]. Numerous studies have demonstrated a significant association between indoor air quality (IAQ) and students' academic performance. Improved classroom ventilation and lower concentrations of CO₂ and particulate matter have been linked to better cognitive function, higher test scores, improved attendance, and enhanced attention and memory among schoolchildren [11].

As indoor air quality in nonresidential buildings (e.g., schools) plays an important role in respiratory health [15]. The *Schools Indoor Pollution and Health: Observatory Network in Europe* (SINPHONIE) project, funded by the European Parliament, assessed indoor air exposure in schools in 23 countries [16]. The study found that PM_{2.5}, some VOCs (e.g., formaldehyde), radon, and allergens (especially molds) were commonly present. Moreover, the *Health Effects of School Environment* (HESE) project [17] reported that 78% and 66% of children attending schools in Norway, Sweden, Denmark, France, and Italy were exposed to PM₁₀ over 50 µg/m³ and to carbon dioxide (CO₂) over 1000 ppm, respectively. Another study from the HESE project investigating the burden of fungi showed that the number of viable molds in indoor air exceeded the maximum standard of 300 cfu/m³ in 33% of participating classrooms [18]. Very recently, these findings were confirmed in a study conducted in Southern Italy. Importantly, this work observed that the concentration of elements from industrial emission was significantly higher in schools located in



urban/industrial areas as compared to rural areas [19], implying that the penetration of outdoor pollutants further deteriorates the quality of indoor air.

Adverse respiratory and neurological health outcomes associated with exposure to indoor air pollutants can secondarily impact educational attainment both in the short and long term [11].

Few studies succeeded in isolating the effects of exposure in the education environment from exposures in the home, while also accounting for socio-economic confounders (e.g., health inequalities across more deprived communities) [20].

Attributing health effects to individual pollutants can be challenging, which some studies account for by using an index covering multiple pollutants.

A holistic approach of both repairing damage to buildings and improving ventilation should ensure that health effects relating to, e.g., damp conditions or uncontrolled ingress of outdoor pollution are minimized.

Together with source control, the provision of adequate ventilation can achieve optimal IAQ in educational buildings. Increasing classroom ventilation rates often results in better performance (e.g., speed of task completion), but there are inconsistencies relating to, e.g., cognitive performance and task error rate, caused by difficulties delineating the impacts of different pollutants on academic performance. Maintaining indoor temperature between 20 °C and 22 °C through natural or hybrid ventilation can also improve academic outcomes [21].

There is evidence of associations between absenteeism and chronic PM exposure, mould, and low ventilation rates. There is a lack of substantial evidence to confirm the associations of absenteeism with VOC or O₃ exposure [22].

Traffic-related air pollution has been found to impact the executive function through task completion speed, as well as exam grades and language/numeracy testing. There is evidence of negative associations between PM_{2.5} and working memory; NO₂ and UFP with reduced cognitive development compounded by long-term exposure; and VOCs and PAHs with cognitive function.

Mechanical and hybrid ventilation systems systematically outperform natural ventilation strategies in terms of achieving a desired air flow rate to provide adequate conditions for both learning and reducing respiratory infection transmission. However, ventilation standards remain unmet in a concerning large proportion of educational buildings, especially schools, even when mechanical ventilation is in place. Depending on national or state public school funding, the capital and operating costs of mechanical ventilation and/or air filtration devices to improve indoor conditions can represent a relatively small fraction of a typical state school budget [23].



3. CASE STUDY: INDOOR AIR QUALITY IN SCHOOLS IN NIŠ, SERBIA

3.1. Study area

The city of Niš is situated in Southern Europe (altitude -190 m) and covers a surface area of about 597 km². It is the third city in Serbia and according to the latest census from 2022 has about 178,976 inhabitants. The location of the city is unsuitable because the whole city area is located in the valley closed from the three sides. The dominant wind is the North West and its direction diverges so that natural airing is obstructed. Niš has moderate continental climate with average annual temperature of about 11,2°C. Temperature inversion is frequent. Wet days are present for more than 100 days a year.

Up to the nearly nineties of the previous century, Niš was an industrial city. The dominant sources of air pollution were industry and heating. Nowadays the dominant sources of air pollution in Niš are individual household heating during the winter months, localized road traffic emissions, and operational emissions from industrial facilities within the region.

We investigated two selected school buildings in Nis that represented the building stock of the region in terms of typology, construction technology, age and the natural ventilation type dominant in the country [24]. School 1 is located at an urban area with major traffic roads surrounding the school building and School 2 is located in a residential area, far from main street.

3.2. Methodology

The sampling was carried out in the heating period in each primary school building from Monday morning to Friday afternoon. The samplers took place only when the classroom was occupied in order to provide a better estimate of exposure. Target air quality parameters investigated in this study were sulfur dioxide (SO₂) and black smoke (BS), nitrogen oxides, formaldehyde and carbon monoxide. The samplers was placed at approximately 0.8 m height indoors, which corresponds to the breathing zone of sitting children, not closer than 1 m to the wall. Simultaneously, sampling and monitoring were undertaken outdoors with identical samplers and monitors at each building.

The pollutants were measured daily, during the heating season. The ambient level of BS was measured by reflectance. The sampling was performed by means of a pump operating with flow rate of 1 L/min through Whatman No1 paper filters. The air concentration of SO₂ was determined by spectrophotometer. The sulfur dioxide present in the air stream reacts with the solution to form a stable monochlorosulfonatomercurate complex. During the subsequent analysis, this complex is brought into reaction with acid-bleached pararosaniline dye and formaldehyde yielding intensely colored pararosaniline methyl sulfonic acid. The optical density of this species is determined spectrophotometrically at 548 nm and was directly related to the amount of sulfur dioxide collected. The total volume of the air sample was determined from the flow rate and the sampling time. The concentration of sulfur dioxide in the ambient air was calculated and expressed in µg/m³. The lowest limit of detection is 1.7 µg/m³. Ambient nitrogen dioxide was collected with a pump containing



triethanolamine in its tube with the exact amount of the reacted nitrogen dioxide using the standard spectrophotometry. The minimum detectable limit of the method had been determined to be 2.0 mg/m^3 . The method for formaldehyde air detection involve collecting air samples followed by spectrophotometric analysis using chromotropic acid and measuring the concentration via spectroscopy. Gas samples were collected using the aspiration method with an SKC Ltd. pump in corridors, sport halls/gymnasiums and two classrooms in every school. Sampling equipment was placed at 1.5 m above floor level at the sampling sites.

A statistical package SPSS was used for data analysis. Air pollution data were analyzed using Mann-Whitney U test. A P value <0.05 was required for significance.

3.3. Results

The results of the monitoring for the sulfur dioxide and black smoke are reported in Table 1 for the investigated primary school buildings.

Table 1. Mean 24-hour values of sulfur dioxide and black smoke

Sampling location	School 1		School 2	
	SO ₂ ($\mu\text{g/m}^3$)	Black smoke ($\mu\text{g/m}^3$)	SO ₂ ($\mu\text{g/m}^3$)	Black smoke ($\mu\text{g/m}^3$)
Corridor	20	4	0	4
Classroom	4	10	0	5
Schoolyard	31	1	20	0
Guideline values	150	50	100	40

Concentrations of SO₂ and black smoke in both schools were below ambient air limit values and occupational exposure limits. In School 2 SO₂ was not detected in the corridor and one classroom while in School 1, SO₂ and black smoke were detected in all sampled rooms.

The results of the monitoring for the gases carbon monoxide, nitrogen dioxide, and formaldehyde are reported in Table 2 for the investigated primary school buildings.

Table 2. Mean values of carbon monoxide, nitrogen dioxide, and formaldehyde

Sampling location	School 1			School 2		
	CO (mg/m^3)	NO _x ($\mu\text{g/m}^3$)	Formaldehyde (mg/m^3)	CO (mg/m^3)	NO _x ($\mu\text{g/m}^3$)	Formaldehyde (mg/m^3)
Corridor	2,8	45,7	7,6	0	21,1	0
Classroom 1	0	38,4	5,7	0	20	0
Sports hall/Gymnasium	0	22,5	4,9	0	22,2	0
Classroom 2	0	27	0	0	21,7	0
Guideline values	5	85	0,1	3	70	0,1



Measured concentrations of CO and NO_x in both schools were below the relevant guideline values. Formaldehyde was detected in the School 1, whereas it was not detected in School 2.

4. DISCUSSION AND RECOMMENDATIONS

The findings presented in this study, together with evidence from international research, confirm that indoor air quality (IAQ) in schools remains an important public health concern. Children represent a particularly vulnerable population due to their physiological characteristics, developing respiratory and immune systems, and the substantial amount of time they spend indoors. Our measurements, as well as previous European studies, indicate that elevated concentrations of carbon dioxide, particulate matter, biological contaminants, and other indoor pollutants are frequently present in school environments, potentially affecting both health and educational outcomes.

Improving IAQ in schools should therefore be recognized as an essential component of sustainable school design and operation. Green building principles provide an effective framework for achieving healthier indoor environments while simultaneously reducing environmental impacts and energy consumption. Rather than focusing solely on energy efficiency, modern green school buildings should integrate strategies that balance energy performance with occupant health and comfort [25].

Adequate ventilation should be a key priority in green school buildings. Mechanical ventilation systems with high-efficiency filtration can significantly reduce indoor concentrations of particulate matter, allergens, and airborne pathogens while maintaining acceptable carbon dioxide levels [26]. Where full mechanical ventilation is not feasible, hybrid systems combining natural and mechanical ventilation may provide a sustainable and cost-effective alternative. Continuous monitoring of carbon dioxide concentrations can help assess ventilation performance and identify areas requiring intervention. In addition, incorporating vegetation through green spaces, green walls, or landscaped buffers around schools may further improve environmental quality by reducing pollutant exposure, enhancing occupants' well-being, and supporting broader sustainability goals [27].

Building design and maintenance also play a critical role in IAQ improvement. Moisture control, prevention of water intrusion, and timely remediation of dampness and mold growth are essential for reducing respiratory symptoms and allergic diseases among students. The use of low-emission construction materials, furniture, paints, adhesives, and cleaning products can further minimize indoor exposure to volatile organic compounds and other harmful chemicals [28].

Green school concepts additionally emphasize the importance of reducing the penetration of outdoor pollutants. Schools located near major roads or industrial zones should incorporate appropriate filtration systems, strategic landscaping, and building envelope improvements to limit the infiltration of traffic-related air pollution. Green roofs, vegetation barriers, and surrounding green spaces may provide additional environmental and health benefits while improving thermal comfort [27].



The implementation of smart building technologies represents another promising approach. Real-time monitoring systems capable of measuring carbon dioxide, temperature, humidity, particulate matter, and other environmental parameters can support evidence-based management of indoor environments. Such systems allow rapid identification of problems and optimization of ventilation and energy use [29].

5. CONCLUSION

Improving IAQ requires multidisciplinary collaboration involving public health professionals, engineers, architects, school administrators, and policy makers. National standards and regulations should increasingly incorporate health-oriented IAQ criteria into school building design, renovation, and operation. Investments in healthy school environments should not be viewed solely as infrastructure costs but as long-term investments in children's health, cognitive development, academic achievement, and overall well-being.

Future efforts should focus on integrating IAQ monitoring into routine school management practices and promoting green building strategies that simultaneously support environmental sustainability, energy efficiency, and occupant health. Such an approach is essential for creating resilient and healthy educational environments in the context of climate change and increasing urbanization.

LITERATURE

- [1] World Health Organization. (2026, April). *Climate change and health*. <https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health>
- [2] Mannan, M., & Al-Ghamdi, S. G. (2021). Indoor air quality in buildings: A comprehensive review on the factors influencing air pollution in residential and commercial structure. *International Journal of Environmental Research and Public Health*, 18(6), 3276. <https://doi.org/10.3390/ijerph18063276>
- [3] Molloy, J., Koplin, J. J., Allen, K. J., et al. (2017). *Vitamin D insufficiency in the first 6 months of infancy and challenge-proven IgE-mediated food allergy at 1 year of age: A case-cohort study*. *Allergy*, 72(8), 1222–1231. <https://doi.org/10.1111/all.13122>
- [4] Yepes-Nunez, J. J., Brozek, J. L., Fiocchi, A., et al. (2018). *Vitamin D supplementation in primary allergy prevention: Systematic review of randomized and non-randomized studies*. *Allergy*, 73(1), 37–49. <https://doi.org/10.1111/all.13241>
- [5] Breyse, P. N., Diette, G. B., Matsui, E. C., Butz, A. M., Hansel, N. N., & McCormack, M. C. (2010). *Indoor air pollution and asthma in children*. *Proceedings of the American Thoracic Society*, 7(2), 102–106. <https://doi.org/10.1513/pats.200908-083RM>
- [6] Piccioni, P., Tassinari, R., Carosso, A., Carena, C., Bugiani, M., & Bono, R. (2015). *Lung function changes from childhood to adolescence: A seven-year follow-up study*. *BMC Pulmonary Medicine*, 15, Article 31. <https://doi.org/10.1186/s12890-015-0028-9>
- [7] Bobak, M., & Leon, D. A. (1992). *Air pollution and infant mortality in the Czech Republic, 1986–88*. *The Lancet*, 340(8826), 1010–1014. [https://doi.org/10.1016/0140-6736\(92\)93017-h](https://doi.org/10.1016/0140-6736(92)93017-h)
- [8] Grimalt, J. (2001). In Stephen T. Holgate, Jonathan M. Samet, Hillel S. Koren and Robert L. Maynard (eds.), *Air Pollution and Health*. <https://doi.org/10.1023/A:1010385517427>



- [9] Roche, I. V., Ubalde-Lopez, M., Daher, C., Nieuwenhuijsen, M., & Gascon, M. (2024). *The health-related and learning performance effects of air pollution and other urban-related environmental factors on school-age children and adolescents: A scoping review of systematic reviews*. *Current Environmental Health Reports*, 11(2), 300–316. <https://doi.org/10.1007/s40572-024-00431-0>
- [10] Katafygiotou, M. C., & Serghides, D. K. (2014). *Indoor comfort and energy performance of buildings in relation to occupants' satisfaction: Investigation in secondary schools of Cyprus*. *Advanced Building Energy Research*, 8, 216–240. <https://doi.org/10.1080/17512549.2013.865554>
- [11] Pulimeno, M., Piscitelli, P., Colazzo, S., Colao, A., & Miani, A. (2020). *Indoor air quality at school and students' performance...* *Health Promotion Perspectives*, 10(3), 169–174. <https://doi.org/10.34172/hpp.2020.29>
- [12] Baloch, R. M., Maesano, C. N., Christoffersen, J., et al. (2020). *Indoor air pollution, physical and comfort parameters related to schoolchildren's health: Data from the European SINPHONIE study*. *Science of the Total Environment*, 739, 139870. <https://doi.org/10.1016/j.scitotenv.2020.139870>
- [13] Sadrizadeh, S., Yao, R., Yuan, F., et al. (2022). *Indoor air quality and health in schools: A critical review for developing the roadmap for the future school environment*. *Journal of Building Engineering*, 57, 104908. <https://doi.org/10.1016/j.jobbe.2022.104908>
- [14] European Federation of Asthma and Allergy Associations. (2001). *The right to breathe healthy indoor air in schools*. https://ec.europa.eu/health/ph_projects/1999/pollution/efa_en.pdf
- [15] Clark, S. N., Anenberg, S. C., & Brauer, M. (2025). *Global burden of disease from environmental factors*. *Annual Review of Public Health*, 46(1), 233–251. <https://doi.org/10.1146/annurev-publhealth-071823-105338>
- [16] Csobod, E. A., Annesi-Maesano, I., Carrer, P., et al. (2014). *SINPHONIE – Schools Indoor Pollution and Health Observatory Network in Europe: Final report*. Publications Office of the European Union. <http://publications.jrc.ec.europa.eu/repository/handle/JRC91160>
- [17] Simoni, M., Annesi-Maesano, I., Sigsgaard, T., et al. (2010). *School air quality related to dry cough, rhinitis and nasal patency in children*. *European Respiratory Journal*, 35(4), 742–749. <https://doi.org/10.1183/09031936.00016309>
- [18] Simoni, M., Cai, G. H., Norbäck, D., et al. (2011). *Total viable molds and fungal DNA in classrooms and association with respiratory health and pulmonary function of European schoolchildren*. *Pediatric Allergy and Immunology*, 22(8), 843–852. <https://doi.org/10.1111/j.1399-3038.2011.01208.x>
- [19] Ruggieri, S., Longo, V., Perrino, C., et al. (2019). *Indoor air quality in schools of a highly polluted south Mediterranean area*. *Indoor Air*, 29(2), 276–290. <https://doi.org/10.1111/ina.12529>
- [20] Fisk, W. J. (2017). *The ventilation problem in schools: Literature review*. *Indoor Air*, 27(6), 1039–1051. <https://doi.org/10.1111/ina.12403>
- [21] Haverinen-Shaughnessy, U., Moschandreas, D. J., & Shaughnessy, R. J. (2011). *Association between substandard classroom ventilation rates and students' academic achievement*. *Indoor Air*, 21(2), 121–131. <https://doi.org/10.1111/j.1600-0668.2010.00686.x>
- [22] Bozzola, E., Agostiniani, R., Pacifici Noja, L., et al. (2024). *The impact of indoor air pollution on children's health and well-being: The experts' consensus*. *Italian Journal of Pediatrics*, 50(1), 69. <https://doi.org/10.1186/s13052-024-01631-y>
- [23] Wargocki, P., & Wyon, D. P. (2013). *Providing better thermal and air quality conditions in school classrooms would be cost-effective*. *Building and Environment*, 59, 581–589. <https://doi.org/10.1016/j.buildenv.2012.10.007>
- [24] Nikolić, M., Stanković, A., Kocić, B., Simonović, J., & Popović, N. (2026). *Assessment of indoor air quality in schools – Significance for healthcare professionals in Serbia*. *Preventivna Pedijatrija*, 12(1–2), 57–62. <https://doi.org/10.46793/PP260131016N>



- [25] Karimi, H., Adibhesami, M. A., Bazazzadeh, H., & Movafagh, S. (2023). *Green buildings: Human-centered and energy efficiency optimization strategies*. *Energies*, 16(9), 3681. <https://doi.org/10.3390/en16093681>
- [26] Otoo, C., Lu, T., & Lü, X. (2024). *Application of mixed-mode ventilation to enhance indoor air quality and energy efficiency in school buildings*. *Energies*, 17(23), 6097. <https://doi.org/10.3390/en17236097>
- [27] Rawat, N., & Kumar, P. (2023). *Interventions for improving indoor and outdoor air quality in and around schools*. *Science of the Total Environment*, 858, 159813. <https://doi.org/10.1016/j.scitotenv.2022.159813>
- [28] Tran, M. T., Wei, W., Dassonville, C., et al. (2023). *Review of parameters measured to characterize classrooms' indoor environmental quality*. *Buildings*, 13(2), 433. <https://doi.org/10.3390/buildings13020433>
- [29] World Green Building Council. (2021). *Health & wellbeing framework: Six principles for a healthy, sustainable built environment (Full report)*. <https://worldgbc.org/wp-content/uploads/2026/05/1.-Framework-Full-PDF-.pdf>