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ASSESSMENT OF INDOOR AIR QUALITY IN SCHOOLS – SIGNIFICANCE FOR HEALTHCARE PROFESSIONALS IN SERBIA

ISPITIVANJE KVALITETA VAZDUHA U ŠKOLAMA – ZNAČAJ ZA ZDRAVSTVENE RADNIKE U SRBIJI

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Summary

Introduction: Children are particularly vulnerable to indoor air pollution due to their physiological characteristics and the substantial amount of time spent in school environments. In Serbia, data on indoor air quality (IAQ) in schools remain limited. Healthcare professionals must rely on international data that may not fully reflect regional building characteristics and climatic conditions.

Objective: The aim of this study was to assess indoor air quality in two primary schools in Niš, Serbia, located in areas with different levels of air pollution - one situated in the central urban zone characterized by higher traffic density and elevated pollution levels, and the other in a suburban spa area with lower levels of ambient air pollution.

Materials and methods: Target air quality parameters investigated in this study were sulfur dioxide (SO_2) and black smoke (BS), nitrogen oxides, formaldehyde, carbon monoxide, and biological agents. The pollutants were measured daily, during the heating season. Gas samples were collected using the aspiration method with an Air Sampling Pump in corridors, sport halls/gymnasiums and two classrooms. Microflora was examined using classical microbiological techniques, by aspiration sampling, in which air was drawn through liquid dextrose broth, as well as by sedimentation on blood agar. Sabouraud dextrose agar was used for the identification of fungi.

Results: Concentrations of SO_2, black smoke and NO_x were consistently higher in the primary school located in the more air polluted area compared to the other school, yet all remained below the relevant national guideline values. Carbon monoxide levels were also higher in school in city center, while being negligible in school in Niška Banja (spa), whereas formaldehyde was detected exclusively in city center school at concentrations exceeding the guideline value. Microbiological analysis showed distinct contamination patterns between the two schools and the presence of coagulase-negative staphylococci, *Enterococcus faecium*, enteric bacteria and *Candida* at one school, while the other school showed predominance of *Bacillus* species with sporadic pathogenic bacteria and saprophytic molds.

Conclusion: This study provides new indoor air quality data from two primary school buildings in the city of Niš, highlighting the need for reduced formaldehyde concentrations and improved risk assessment approaches to support the development of national IAQ action plans in Serbia.

Keywords: indoor air, children, school

Sažetak

Uvod: Deca su posebno osetljiva na zagađenje vazduha u zatvorenom prostoru zbog svojih fizioloških karakteristika i značajne količine vremena provedenog u školskom okruženju. U Srbiji su podaci o kvalitetu vazduha u zatvorenom prostoru (Indoor Air Quality – IAQ) u školama i dalje ograničeni. Zdravstveni radnici se moraju oslanjati na međunarodne priznate preporuke koje možda ne odražavaju u potpunosti regionalne karakteristike zgrada i klimatske uslove.

Cilj: Cilj ove studije bio je da proceni kvalitet vazduha u dve osnovne škole u Nišu, u Srbiji, koje se nalaze u područjima sa različitim nivoima zagađenja vazduha, jednoj u centralnoj gradskoj zoni sa većim intenzitetom saobraćaja i višim nivoima zagađenja, i drugoj u prigradskom banjskom području sa nižim nivoima ambijentalnog zagađenja.

Materijali i metode: Ciljani parametri kvaliteta vazduha koji su ispitivani u ovoj studiji bili su sumpor-dioksid (SO_2) i čađ (Black Smoke – BS), azotni oksidi (NOx), formaldehid, ugljen-monoksid i biološki agensi (mikroflora). Nivoi zagađujućih materija su se merili svakodnevno, tokom grejne sezone. Uzorci gasova su prikupljani aspiracionom metodom pomoću pumpe za uzorkovanje vazduha u hodnicima, fiskulturnim salama i u dve učionice. Mikroflora je ispitivana klasičnim mikrobiološkim tehnikama, aspiracionim uzorkovanjem, pri čemu je vazduh propuštan kroz tečni dekstrozni bujon, kao i sedimentacionom metodom na krvnom agaru. Za identifikaciju gljivica korišćen je Saburo dekstrozni agar.

Rezultati: Koncentracije SO_2, čađi i NOx bile su konstantno više u školi Radoje Domanović u poređenju sa školom Ivan Goran Kovačić, ali su sve ostale ispod relevantnih vrednosti. Nivoi ugljen-monoksida takođe su bili viši u školi u centru grada a zanemarljivi u školi u Niškoj Banji, dok je formaldehid detektovan isključivo u školi Radoje Domanović u koncentracijama koje prelaze preporučenu vrednost. Mikrobiološka analiza je pokazala različite obrasce kontaminacije između dve škole: školu Radoje Domanović karakterisalo je prisustvo koagulaza-negativnih stafilokoka, *Enterococcus faecium*, enterobakterija i *Candide*, dok je u školi Ivan Goran Kovačić najviše bilo *Bacillus*-a, sporadičnih patogenih bakterija i saprofitskih plesni, što ukazuje na neadekvatne higijenske i ventilacione uslove u obe ustanove.

Zaključak: Ova studija pruža nove podatke o kvalitetu vazduha u dve osnovne škole u Nišu, ukazujući na potrebu za smanjenjem koncentracija formaldehida i unapređenjem pristupa proceni rizika, u cilju podrške razvoju nacionalnih planova za kvalitet vazduha u zatvorenim prostorijama u Srbiji.

Ključne reči: unutrašnji vazduh, deca, škola

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INTRODUCTION

Most people spend approximately 90 per cent of their time indoors (1). 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. Children's breathing rates are higher than those of adults and they also take in more air per kilogram of body weight. 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. Children's bodies and organs, including their lungs, are also still in development, which further increases risk (2). Furthermore, children's developing immune systems are weaker than those of adults, strengthening the effects of pollution.

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 (3). 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 (4).

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 (5). 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 (6).

The health implications of poor IAQ in schools extend beyond pediatric populations and have direct relevance for healthcare professionals. Pediatricians, family physicians, epidemiologists and public health practitioners are often the first to encounter children's health complaints potentially linked to indoor environmental exposures. Symptoms such as recurrent respiratory infections, persistent cough, wheezing, headaches, fatigue and decreased concentration may be non-specific and easily overlooked unless environmental factors are systematically considered during clinical assessment. Therefore, awareness and understanding of IAQ-related health risks are essential competencies for healthcare workers involved in child and adolescent health care (7).

The healthcare professionals play a crucial role in recognizing environmentally mediated diseases, initiating early interventions and advising both families and institutions on risk reduction strategies. International guidelines, including those developed by the International Society of Indoor Air Quality and Climate, highlight the importance of routine monitoring of IAQ parameters in schools and the integration of environmental health considerations into public health practice. Healthcare professionals are key stakeholders in translating scientific evidence into practical recommendations, participating in multidisciplinary collaborations, and advocating for healthier school environments at local and national levels (8,9).

In Serbia, data on IAQ in schools remains limited. This lack of locally relevant evidence poses a challenge for healthcare professionals, who must rely on international data that may not fully reflect regional building characteristics, climatic conditions or regulatory frameworks. Strengthening the evidence base on IAQ in Serbian schools is therefore essential for supporting clinical decision-making, improving environmental risk assessment and enhancing preventive health strategies targeting school-aged children (10).

OBJECTIVE

The aim of this study was to assess indoor air quality in two primary schools in Niš, Serbia, located in areas with different levels of air pollution - one situated in the central urban zone characterized by higher traffic density and elevated pollution levels, and the other in a suburban spa area with lower levels of ambient air pollution, provide new data and contribute to the development of national action plans for improving air quality in schools in Serbia.

MATERIALS AND METHODS

Two primary school buildings were investigated in the city of Niš, Serbia. Niš city covers an area of 596.71 km ^{2}, and with a population of 250.648 inhabitants, according to the population census from 2022. The two study areas (polluted and non-polluted) of the city were carefully selected based on significant difference in annual mean concentrations of sulfur dioxide (SO_2) and black smoke (BS) in the past 10 years. The selected school buildings must represent the building stock of the region in terms of typology, construction technology, age and the natural ventilation type dominant in the country. The first school "Radoje Domanović" is located in the city center, near a heavily trafficked intersection defined as a "black spot," and is connected to the district heating system. This measuring spot often experiences "poor" or "extremely polluted" air, with black smoke, SO_2 and NO_x levels exceeding safety standards by more than half days at the year, especially at winter, The second school "Ivan Goran Kovačić" is situated in Niška Banja (spa), with own heating system and located in one of the less polluted parts of the wider urban area. One classroom occupied by children aged between seven and ten years was selected in each building and the classroom is representative of the school and occupied by the same children for the whole school year. The willingness of school managers and teachers for participation in the study was obtained during the selection procedure.

The sampling was carried out in the heating period in each primary school building from Monday morning to Friday afternoon. The sampling 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 (SO_2) and black smoke (BS), nitrogen oxides, formaldehyde, carbon monoxide, and biological agents (microflora). 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 Whattman No1 paper filters. The air concentration of SO_2 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 $\mu g/m^3$. The lowest limit of detection is 1.7 $\mu g/m^3$. 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.

Microflora was examined using classical microbiological techniques that involve passive (settle plates) sampling methods to collect viable microorganisms onto culture media, followed by incubation and colony counting, the air was drawn through liquid dextrose broth, as well as by sedimentation on blood agar. Sabouraud dextrose agar was used for the identification of fungi. Sampling included two classrooms, a corridor and a sport hall/gymnasium.

The investigated sites were described with respect to general information, building materials, quality of the surrounding environment, ventilation, furnishing, activities in the classroom, etc. The checklists were filled in by the specialist in hygiene and the facility manager during the week of sampling.

The evaluation of the potential health effects of the IAQ can be performed based on the comparison of the measured values with the corresponding guidelines, thresholds, or national target/limit values for ambient air.

RESULTS

The results of the monitoring for the sulfur dioxide and black smoke are reported in Table 1 and table 2 for the investigated primary school buildings.

Table 1 Mean 24-hour values of sulfur dioxide and black smoke in the school "Radoje Domanović"- city center school

Sampling location	SO_2 (μg/m³)	Black smoke (μg/m³)
Corridor	20	4
Classroom	4	10
Schoolyard	31	1

Table 2 Mean 24-hour values of sulfur dioxide and black smoke in the school "Ivan Goran Kovačić"- school in a spa resort area

Sampling location	SO_2 (μg/m³)	Black smoke (μg/m³)
Corridor	0	4
Classroom	0	5
Schoolyard	20	0

Concentrations of SO_2 and black smoke in both schools were below ambient air limit values and occupational exposure limits. In the Niška Banja School SO_2 was not detected in the corridor and one classroom. In the "Radoje Domanović" school, SO_2 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 3 and table 4 for the investigated primary school buildings.

Table 3 Mean values of carbon monoxide, nitrogen dioxide, and formaldehyde in the school "Radoje Domanović" – city center school

Sampling location	CO (mg/m³)	NO_x (μg/m³)	Formaldehyde (mg/m³)
Corridor	2,8	45,70	7,60
Classroom 1	0,0	38,40	5,70
Sports hall/Gymnasium	0,0	22,50	4,90
Classroom 2	0,0	27,00	0,00

Table 4 Mean values of carbon monoxide, nitrogen oxides, and formaldehyde in the school "Ivan Goran Kovačić"- school in a spa resort area

Sampling location	CO (mg/m³)	NO_x (μg/m³)	Formaldehyde (mg/m³)
Corridor	0,0	21,10	0,00
Classroom 1	0,0	20,00	0,00
Sports hall/Gymnasium	0,0	22,20	0,00
Classroom 2	0,0	21,70	0,00

Measured concentrations of CO and NO_x in both schools were below the relevant guideline values. Formaldehyde was detected in the "Radoje Domanović" school, whereas it was not detected in the Niška Banja School.

The following charts (Figure 1-5) present the mean concentrations of SO_2, black smoke, NO_x, CO, and formaldehyde measured in two different schools. For each pollutant, levels observed in "Radoje Domanović" school (RD) and "Ivan Goran Kovačić" school (IGK) are compared and evaluated against the corresponding guideline values (IAQ GV). This comparative approach allows for the identification of differences in indoor air quality between the two school environments, as well as an assessment of compliance with recommended exposure limits and potential health risks.

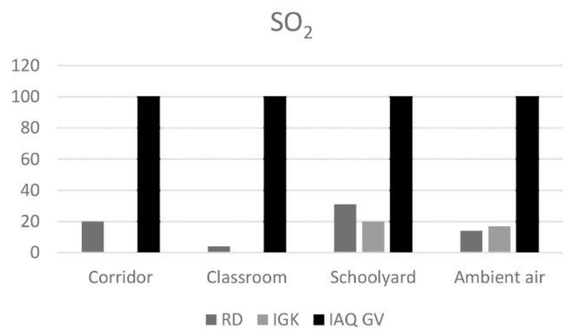

Figure 1 Mean SO_2 air levels in two different schools

Concentrations of SO_2 were consistently higher in the "Radoje Domanović" (RD) school compared to the "Ivan Goran Kovačić" (IGK) school across all sampled locations. In RD, the highest values were recorded in the schoolyard, followed by the corridor and ambient air, while the lowest concentration was measured in the classroom. In the IGK school, SO_2 was detected only in the schoolyard and ambient air, whereas no detectable concentrations were observed in the corridor or classroom. All measured values in both schools remained below the applicable indoor air quality guideline values (Figure 1).

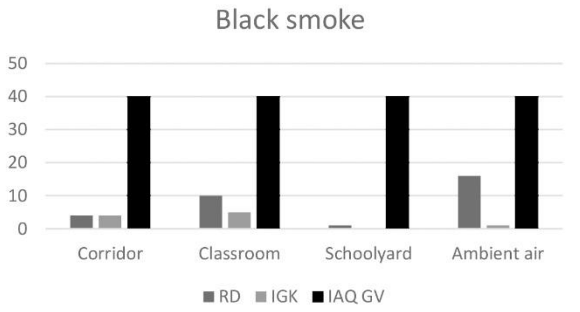

Figure 2 Mean black smoke (BS) air levels in two different schools

The figure 2 shows the distribution of black smoke levels across different school environments (corridor, classroom, schoolyard, and ambient air). In "Radoje Domanović" school values vary, with the highest levels observed in ambient air and classroom samples, while the lowest value is recorded in the schoolyard. Values in "Ivan Goran Kovačić" school are generally low in all locations, with slightly higher values in the corridor and classroom compared to the schoolyard and ambient air.

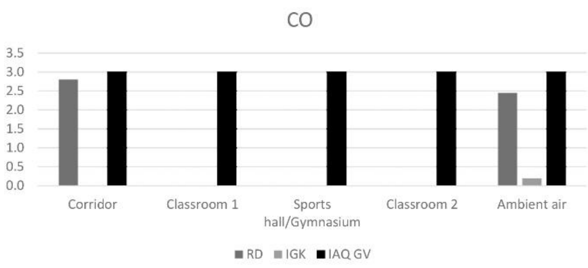

Figure 3 Mean CO air Levels in two different schools

Carbon monoxide (CO) concentrations were measured in different locations to assess air quality. In the corridor of "Radoje Domanović" School, CO levels were elevated. Similarly, ambient air measurements at "Radoje Domanović" School showed high CO concentrations. In contrast, ambient air at "Ivan Goran Kovačić" School contained detectable levels of CO, but these were considerably lower than those observed at "Radoje Domanović" School (Figure 3).

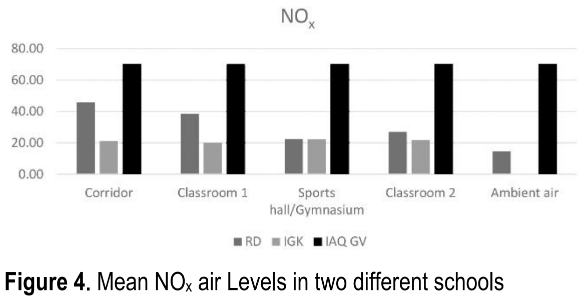

Figure 4. Mean NO_x air Levels in two different schools

Nitrogen oxides (NOx) concentrations were higher across all indoor locations in "Radoje Domanović" School compared to "Ivan Goran Kovačić" School, with the school corridor consistently showing the highest levels. In both schools, the sports hall exhibited lower NOx concentrations relative to classrooms and corridors. Ambient air measurements outside the schools reflected the same pattern, with levels near zero at "Ivan Goran Kovačić" School and moderately elevated at "Radoje Domanović" School. Despite these differences, NOx concentrations in both schools remained below the established guideline value (Figure 4).

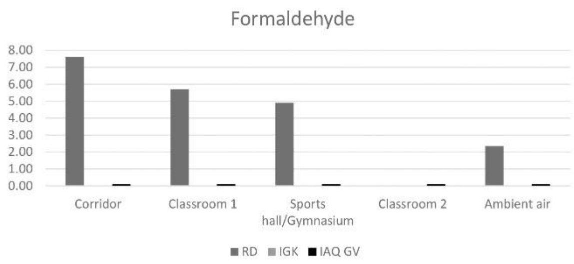

Figure 5 Mean Formaldehyde air Levels in in two different schools

Formaldehyde was detected exclusively in the "Radoje Domanović" (RD) school. The highest concentration was measured in the corridor, followed by Classroom 1 and the sports hall/gymnasium, while lower values were observed in ambient air. No formaldehyde was detected in Classroom 2 of the RD school or in any of the sampled locations in the "Ivan Goran Kovačić" (IGK) school. All recorded concentrations were below the applicable guideline values (Figure 5).

Microflora was examined in 18 air samples. The assessment of exposure of the school population was performed in eight working rooms and in the school yard during class time, with windows closed (table 5, table 6).

Table 5 Microflora in indoor air samples in the school "Radoje Domanović"

No.	Sampling location	Number of colonies
1	Classroom VIII/1	*Coagulase-negative staphylococci (CoNS)* 53, *Candida* sp. 10, *Alternaria* sp. 25, B:0
2	Corridor	*Coagulase-negative staphylococci (CoNS)* 120, *Penicillium* sp. 15, *Scopulariopsis* 10, *Candida* sp. 5, B:0
3	Classroom IV/3	*Coagulase-negative staphylococci (CoNS)* 52, *Candida* sp. 30, *Candida albicans* 15, B:0
4	Preschool room	Saprophytes 75, *Candida* sp. 10, B:0
5	Cafeteria/ Dining room	*Enterobacter* sp. 15, *Serratia* sp. 20, saprophytes 150, *Penicillium* 10, *Candida* sp. 8, B: *Enterobacter* sp. 10, *Serratia* sp. 5
6	Classroom VI/2	*Enterococcus faecium* 30, saprophytes 150, *Aspergillus* sp. 12, *Penicillium* sp. 5, *Candida albicans* 8, B:0
7	Sports hall/ Gymnasium	Saprophytes 120, *Alternaria* 10, *Penicillium* sp. 2, *Scopulariopsis* 15, B:0
8	Technical classroom/ Workshop room	Saprophytes 180, *Candida* sp. 25, B:0
9	Schoolyard	Saprophytes 30, *Candida* sp. 20, *Penicillium* sp. 10, *Mucor* sp. 8, B:0

Table 6 Microflora in indoor air samples in the school "Ivan Goran Kovačić"

No.	Sampling location	Number of colonies
1	Classroom 1 - east	*Serratia* sp. 30, *Coagulase-negative staphylococci (CoNS)* 20, saprophytes 120, *Candida* sp. 10, *Phoma* sp., B: *Coagulase-negative staphylococci (CoNS)* 55, saprophytes 150
2	Classroom 1 - west	*Bacillus subtilis* 12, *Bacillus cereus* 25, *Coagulase-negative staphylococci (CoNS)* 39, *Candida* sp., *Rhizopus* sp., B: *Staphylococcus aureus* 28, *Coagulase-negative staphylococci (CoNS)* 100, *Bacillus* sp. 30
3	Corridor	*Bacillus subtilis* 18, *Bacillus* sp. 58, Torula *Mucor* sp., B: *Bacillus subtilis*, *Enterococcus faecalis* 18, *Escherichia coli* 10
4	Sports hall/ Gymnasium	*Bacillus* sp. 40, *Bacillus cereus* 12, *Bacillus subtilis* 8, *Coagulase-negative staphylococci (CoNS)* 30, *Rhizopus* sp., *Phoma* sp., *Candida* sp., B: *Coagulase-negative staphylococci (CoNS)* 75, *Bacillus* sp. 15
5	Cafeteria/ Dining room	*Bacillus cereus* 15, *Bacillus subtilis* 21, *Coagulase-negative staphylococci (CoNS)* 20, *Candida* sp., *Mucor* sp., B: *Enterococcus faecium* 45
6	Classroom 2 - east	*Bacillus subtilis* 25, *Coagulase-negative staphylococci (CoNS)* 38, B: *Coagulase-negative staphylococci (CoNS)* 25
7	Classroom 2 - west	*Coagulase-negative staphylococci (CoNS)* 15, *Escherichia coli* 5, B: *Escherichia coli* 7
8	Technical classroom/ Workshop room	*Staphylococcus aureus* 10, *Coagulase-negative staphylococci (CoNS)* 55, *Candida* sp., B: *Staphylococcus aureus* 4, saprophytes 35
9	Schoolyard	*Coagulase-negative staphylococci (CoNS)* 30, *Candida* sp., *Mucor* sp., *Phoma* sp., B:0

DISCUSSION

Based on our results, the levels of SO_2 and black smoke in the air of both schools did not exceed the ambient air limit values and remained well below the maximum permissible concentrations for work environments. Unlike the school in Niška Banja, where SO_2 in the air was absent in certain rooms (corridor and classroom), the "Radoje Domanović" school exhibited detectable concentrations of SO_2 and black smoke in all premises. Black smoke was present in minimal concentrations in all premises and was not in Niška Banja School.

Comparison with our previous results (11), a marked decrease in SO_2 and black smoke level in the outdoor environment is also detected in the city of Niš and, consequently, in the yard of the "Radoje Domanović" school complex. In 1982, significantly elevated concentrations of black smoke were recorded inside this school. At the school in Niška Banja, no changes in SO_2 and black smoke concentrations were observed.

All measured values of CO and NO_x do not cause health consequences, while formaldehyde concentrations in the "Radoje Domanović" school were alarmingly high. In contrast, no formaldehyde was detected in the Niška Banja School. The mean and median formaldehyde concentration values were slightly lower in the InAirQ project (12) than the results reported in our study. The different sampling strategy (i.e., sampling only during the teaching hours) and source characteristics could have led to lower formaldehyde concentration values. However, lower concentration values were measured in the InAirQ study compared with the AIRMEX study (13).

Air pollution by microorganisms is noteworthy, as these organisms indicate various physical activities in the space, the presence of a large number of occupants and the state of hygiene, both personal and collective. It remains uncertain whether the number of airborne bacteria directly correlates with increased infection rates.

In the School "Radoje Domanović," detected microorganisms - coagulase-negative staphylococci (CoNS), isolated in classrooms and corridors on the ground floor, pathogenic *Enterococcus faecium* and conditionally pathogenic *Enterobacter* and *Serratia*, identified in the dining room and the upstairs classroom clearly indicate poor indoor hygiene, particularly given the abundance of saprophytic colonies.

At the school in Niška Banja, *Bacillus subtilis* was predominant. Among the pathogens, fecal streptococci A were found in the ground-floor hallway; pathogenic *Staphylococcus aureus* in the ground-floor classroom; *Serratia* on the east side; and *Escherichia coli* in the technical cabinet and classrooms on the west side of the first floor. Different numbers of CoNS colonies were recorded in all rooms, serving as an indicator of infectious pathogenic cocci.

Indicators of poor room ventilation and high humidity included the presence of mold contaminants and *Candida*. *Candida*, which strongly indicates inadequate hygiene, was found in large numbers in the Niš School. Saprophytic molds of the *Mucor*, *Torula*, *Rhizopus* and *Phoma* genera predominated in the Niška Banja School.

More parameters and specific data should be obtained from in-site measurements at other schools to get a more in-depth understanding indoor air contamination in schools. According to our results, there is a need to encourage and train teachers, parents and children in this field. Scientific activities and seminars are necessary to improve the knowledge and perception regarding the importance of indoor air quality at schools (14). It is found that children can be valuable contributors in co-designing classroom environments (15). Therefore, it may be possible to learn more about the needs of children and their ideas for improving indoor air quality.

Schools must manage air pollutants, as poor IAQ can lead to headaches, respiratory irritation, and aggravated asthma among children. Key actions include ensuring adequate ventilation (HVAC maintenance), using air filters, and minimizing pollutants like cleaning chemicals and mold. Healthcare workers manage chronic conditions like diabetes or asthma, ensuring pupils can safely participate in school. For the implementation of measures aimed at protecting children from undesirable environmental factors, including air pollution, good cooperation with their families is always necessary, both in regular circumstances and in emergency situations (16). Promoting healthy lifestyles through education on nutrition, exercise, and hygiene is useful also in this situation.

Limitations of the study are evident due to the following aspects: a short-term monitoring may not reflect a "long-term" situation at the school, the investigation of the IAQ in one classroom per building may not be representative for the other rooms; and knowledge and practice of children and teachers were not investigated.

CONCLUSION

To conclude, it is important to investigate IAQ in primary school buildings whether national and international studies continuously report existing problems or highlight new concerns to protect the health of schoolchildren. Our study provides a new dataset for IAQ investigated in two primary school buildings in Nis city. To protect the health of schoolchildren, preventive measures should include: improving natural and mechanical ventilation in corridors and classrooms, minimizing indoor sources of combustion and pollutants, and regularly monitoring SO_2, black smoke, CO, NOx and formaldehyde levels. In addition, schools should implement routine maintenance of heating systems and adopt low-emission materials for building and furnishing. These findings provide evidence to support the development of national action plans and school-level IAQ management strategies in Serbia.

References

1. Mannan M, Al-Ghamdi SG. Indoor air quality in buildings: A comprehensive review on the factors influencing air pollution in residential and commercial structure. Int J Environ Res Public Health. 2021;18(6):3276. doi: 10.3390/ijerph18063276
2. Roche IV, Ubalde-Lopez M, Daher C, Nieuwenhuijsen M, Gascon M. 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. Curr Environ Health Rep. 2024; 11(2): 300-316.
3. Katafygiotou MC, Serghides DK. Indoor comfort and energy performance of buildings in relation to occupants' satisfaction: investigation in secondary schools of Cyprus. Adv Build Energy Res. 2014;8:216-240.
4. Baloch RM, Maesano CN, Christoffersen J, Banerjee S, Gabriel M, Csobod E, et al. Indoor air pollution, physical and comfort parameters related to schoolchildren's health: data from the European SINPHONIE study. Sci Total Environ. 2020;739.
5. Sadrizadeh S, Yao R, Yuan F, Awbi H, Bahnfleth W, Bi Y, et al. Indoor air quality and health in schools: a critical review for developing the roadmap for the future school environment. J Build Eng. 2022;57:104908. doi: 10.1016/j.jobe.2022.104908.
6. European Federation of Asthma and Allergy Associations (EFA). The right to breathe healthy indoor air in schools. Brussels: European Federation of Asthma and Allergy Associations; 2001.
7. Murphy J, Tharumakunarajah R, Holden KA, King C, Lee AR, Rose K, Hawcutt DB, Sinha IP. Impact of indoor environment on children's pulmonary health. Expert Rev Respir Med. 2023; 17(12): 1249-1259. doi: 10.1080/17476348.2024.2307561
8. Romanello M, Walawender M, Hsu SC, Moskeland A, Palmeiro-Silva Y, Scamman D, et al. The 2024 report of the Lancet Countdown on health and climate change: facing record-breaking threats from delayed action. Lancet. 2024; 404(10465): 1847-1896. doi: 10.1016/S0140-6736(24)01822-1
9. Toyinbo O, Hägerhed L, Dimitroulopoulou S, Dudzinska M, Emmerich S, Hemming D, et al. Open database for international and national indoor environmental quality guidelines. Indoor Air. 2022; 32(4): 13028. doi:10.1111/ina.13028
10. Matic B, Rakic U, Jovanovic V, Dejanovic S, Djonovic N. Key Factors Determining Indoor Air PM10 Concentrations in Naturally Ventilated Primary Schools in Belgrade, Serbia. Zdr Varst. 2017; 56(4): 227-235. doi: 10.1515/sjph-2017-0031
11. Ćirić B, Nikolić M. Kvalitet vazduha unutrašnjih prostorija i karakteristike totalne ekspozicije. In: Zbornik rezimea VIII Kongresa preventivne medicine Jugoslavije sa međunarodnim učešćem; 1995; Beograd. p. 272-273.
12. Szabados M, Csákó Z, Kotlík B, Kazmarová H, Kozajda A, Jutraz A, et al. Indoor air quality and the associated health risk in primary school buildings in Central Europe – the InAirQ study. Indoor Air. 2021;31(4):989-1003. doi: 10.1111/ina.12802
13. Geiss O, Giannopoulos G, Tirendi S, Barrero-Moreno J, Larsen BR, Kotzias D. The AIRMEX study - VOC measurements in public buildings and schools/kindergartens in eleven European cities: statistical analysis of the data. Atmos Environ. 2011;45(22):3676-3684.
14. Ekren O, Karadeniz ZH, Atmaca I, Ugranli-Cicek T, Sofuoglu SC, Toksoy M. Assessment and improvement of indoor environmental quality in a primary school. Sci Technol Built Environ. 2017;23:391-402.
15. Bluyssen PM, Kim DH, Eijkelenboom A, Ortiz-Sanchez M. Workshop with 335 primary school children in The Netherlands: what is needed to improve the IEQ in their classrooms? Build Environ. 2020;168:106486.
16. Milošević J, Bekić I, Jocić N. The importance of coordination of the healthcare team and the family for the application of early interventions in an emergency situation. Prev Ped. 2025;11(1-2):39-41.