

Original Research

**URBAN AIR QUALITY MEASURED CLOSE TO SCHOOLS AND
KINDERGARTENS WITHIN THE LOCAL MONITORING NETWORK IN SERBIA**

DOI: 10.5937/EcoTER26175M

Branislava I. Matić^{1,a*}, Valentina M. Vukmanović^{1,b}, Snežana V. Živković Perišić^{1,c}

¹ Institute of Public Health of Serbia, Dr Subotića 5, 11000 Belgrade, SERBIA

^a <https://orcid.org/0000-0001-8989-7499>

^b <https://orcid.org/0009-0001-5810-0624>

^c <https://orcid.org/0000-0001-6435-1190>; <https://orcid.org/0009-0007-9198-9385>

Abstract

Exposing children to environmental pollutants during periods significant for their physiological development can lead to long-lasting health effects, dysfunction, and disease. Aim of this paper was to focus on a relatively scarce ambient AQ monitoring practice at the locations of preschool and school facilities in Serbia, within the local network of AQ monitoring stations. This was a cross-sectional study covering period 2015 to 2024.

Measuring points (SO₂, NO₂, soot, PM₁₀) were in front of kindergartens, primary and high schools in urban settlements. Results originate from the continuous public health programme conducted by the Institute of Public Health of Serbia. In sum, both the absolute number of urban ambient AQ measuring points monitored by the local network of Institutes of Public Health and those in front of the educational facilities have increased in this period: from 73/17 to 185/29. Namely, these facilities are chosen more seldom within researched time frame, dropping from 23.29% to 15.12% of all AQ monitoring points. As such facilities are mainly located at important urban intersections, in order to assess the exposure to air pollution of vulnerable population groups (children from preschool to adolescence age), it is recommended to locate more measuring points near them.

Keywords: preschool and school facilities, ambient air quality, measuring points.

INTRODUCTION

According to their location, schools in the administrative area of large cities can be positioned in the central urban core of the city, in the broader urban area and in rural suburbs, which determines the potential risks from the environment [1]. Given the length of time children spend in school, the school environment represents a significant microclimatic environment, in terms of the impact of air pollution on their respiratory health, above all. According to *International Review of Curriculum and Assessment Frameworks Internet Archive* children in developed countries spend 175 to 220 days a year in school, five to eight hours a day [2].

The aim of this paper was to focus on a relatively scarce ambient AQ monitoring practice at the locations of preschool and school institutions in Serbia, within the local network of AQ monitoring stations.

* brankicam@batut.org.rs

MATERIALS AND METHODS

The research tool used in this cross-sectional study is a data base formed and regularly updated by the Institute of Public Health of Serbia (IPHS), as a segment of a continuous AQ monitoring process implemented for the Ministry of Health, through regular reporting of local IPHs from the Network. Sampling, measuring and analyzing level of defined indicators are done by environmental health departments of local / regional IPHs. Data collation, processing and analysis are undertaken by the IPHS, whose assignment is to forward its remarks on possible public health risks to decision-makers. Due to the clear market conditions established in the field of operation of accredited laboratories, the data collected at the IPHS may vary from year to year [3].

Indicators that are monitored are grouped according to the nature of pollution sources, population coverage, traffic density and potential public health risks: SO₂, soot, NO₂, PM₁₀ and atmospheric deposition. Together with the key stakeholders at the local level (local self-government, local IPH), each municipality/town produces a Local Action Plan for AQ monitoring, defining the time schedule of monitoring activities and spatial distribution of sampling points, sources of air pollution and choice of pollutants in need of monitoring. Sulphur dioxide and soot are measured daily due to the strong correlation among their ambient air concentrations and fossil fuel combustion, as Serbia's key energy source is lignite coal [4]. NO₂ is the most frequently measured specific pollutant, on daily basis. Presence of particulate pollution in ambient air is monitored through sampling of coarse particles of total atmospheric deposition (mg/m²/day), PM₁₀ and PM_{2.5}, with different measurement frequency, according to local AQ monitoring plans and specific indication, depending on pollution sources and financial resources of the local administration and the polluter, *per se*.

RESULTS AND DISCUSSION

Table 1 shows precise GIS location of all measuring points: primary schools (PS), kindergartens (KG) and High schools (HS); SOS Children's Village together with the selected pollutants monitored. The exception among these educational institutions is the SOS Children's Village (Sremska Kamenica), as the site is not only a teaching, but also a residential space, where complete care is taken of children without parental care in an organized and humane way. The fact that children are going through all of their daily routine at the same spot could be the reason why at this site the most number and type of pollutants are monitored simultaneously.

Although the total number of measuring points in the Local AQ monitoring network for the period 2015–2024 is, actually, increasing, the number of educational facilities used as sampling points is in decline (Figures 1 and 2).

Table 1 GIS coordinates of educational facilities involved in monitoring

Facilities (29)		GIS	Pollutants monitored
PRIMARY SCHOOLS (15)			
Rakovica, Beograd	„Nikola Tesla”	44°44'47.55" N 20°26'21.56" E	SO ₂ , soot, NO ₂ , indicative: PM ₁₀ with heavy metals analysis (As, Cd, Ni, Pb), B(a)P
Obrenovac, Beograd	„Jefimija”	44°40'06.67" N 20°11'45.50" E	SO ₂ , soot, NO ₂ , PM ₁₀ , AD
Višnjica, Beograd	"Pavlović Barili"	44°49'04.88" N 20°32'04.86" E	SO ₂ , soot, NO ₂ , benzene
Valjevo	"Sestre Ilić"	44°16'09.59" N 19°52'53.01" E	SO ₂ , soot, NO ₂
Vranje	„Sv. Marković”	42°32'01.88" N 21°53'53.90" E	SO ₂ , soot, NO ₂ , AD
	„J.J.Zmaj”	42°54'71" N 21°89'28" E	
	„Predrag Devedić”	42°55'58" N 21°89'95" E	
Vranjska Banja	„Vuk Karadžić”	42°54'38.81" N 20°50'19.10" E	SO ₂ , soot, NO ₂ , AD
Zvečan	„Mito Igumanović”	43°59'40.50" N 19°54'25.85" E	SO ₂ , soot, NO ₂
Kosjerić	„Stanislav Sremčević”	44°00'39.44" N 20°53'43.49" E	AD
Kragujevac	„M. Jovanović”	44°01'48.66" N 20°54'20.54" E	SO ₂ , soot, NO ₂ , PM ₁₀ with heavy metals analysis (Pb, Cd, As, Ni)
	"Đura Jakšić",	45°17'59.45" N 19°56'26.56" E	SO ₂ , NO ₂ , PM ₁₀ with heavy metals analysis (Pb, Cd, Ni, As), B(a)P, PM _{2.5}
Požarevac	„Kralj Aleksandar I”	44°36'52.2" N 21°10'49.9" E	SO ₂ , soot, NO ₂ , AD with heavy metals analysis (Pb, Cd, Zn)
Vranovo	„Dositej Obradović”	44°39'50.55" N 20°55'27.08" E	PM ₁₀ with heavy metals analysis (Pb, Cd, Ni, As), B(a)P
Subotica	"S. Marinković" Mala škola	46°05'34" N 19°40'20" E	PM ₁₀ with heavy metals analysis (Pb, Cd, Ni, As)
KINDERGARTENS (11)			
Valjevo	"Bubamara"	44°16'33.64" N 19°52'24.96" E	SO ₂ , soot, NO ₂
	„Pčelica”	44°17'01.21" N 19°52'21.99" E	
	„Kolibri”	44°16'56" N 19°55'3" E	
	"Vidra"	44°15'54.16" N 19°53'49.96" E	
		42°54'39.92" N 20°50'12.94" E	
Zvečan		43°06'16.98" N 20°48'08.91" E	atmospheric deposition (AD)
Leposavić	Kindergartens	43°10'09.83" N 20°44'23.68" E	
Lešak		42°55'24.72" N 20°40'22.58" E	
Zubin Potok		42°99'49" N 21°95'63" E	
Leskovac		44°01'48.22" N 20°57'06.44" E	
Kragujevac	Ilićevo, „Čuperak”	43°50'40.83" N 19°53'45.09" E	SO ₂ , soot, NO ₂ , AD with heavy metals analysis (Pb, Cd, Zn)
Sevojno	„Maslačak”		SO ₂ , soot, NO ₂
HIGH SCHOOLS (3)			
Kragujevac	Medical	44°01'11.79" N 20°54'33.36" E	AD with heavy metals analysis (Pb, Cd, Zn)
Leskovac	Medical	42°99'64" N 21°93'63" E	SO ₂ , soot, NO ₂ , AD with heavy metals analysis (Pb, Cd, Zn)
Sremska Mitrovica	Economics	42°58'45.61" N 19°35'18.86" E	SO ₂ , soot, NO ₂
Sremska* Kamenica	SOS Children's Village	45°13'31.41" N 19°50'42.69" E	SO ₂ , NO ₂ , NO, NO _x , CO, O ₃ , BeToXy, PM ₁₀ with heavy metals analysis (Pb, Cd, Ni, As), B(a)P, PM _{2.5}

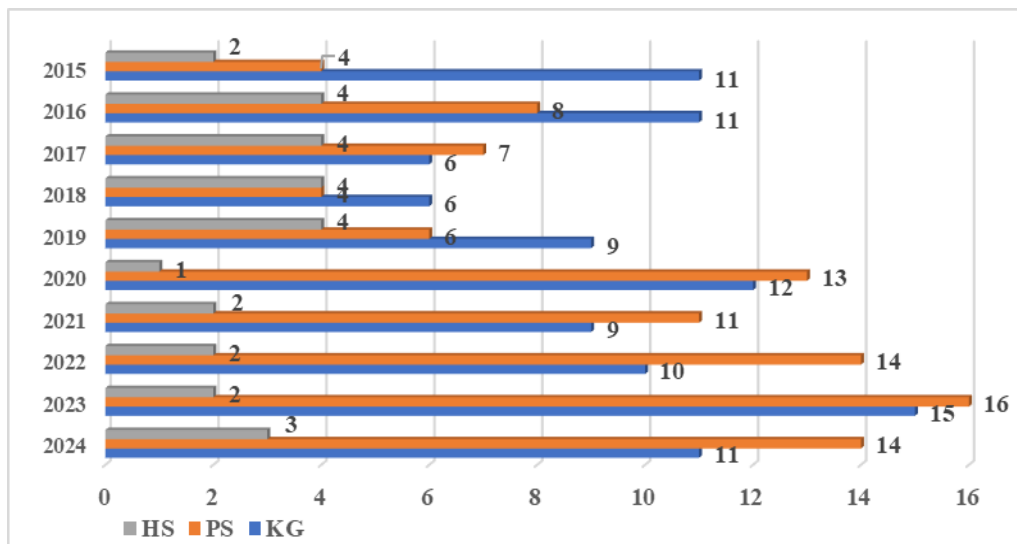


Figure 1 No. of measuring points in front of educational facilities

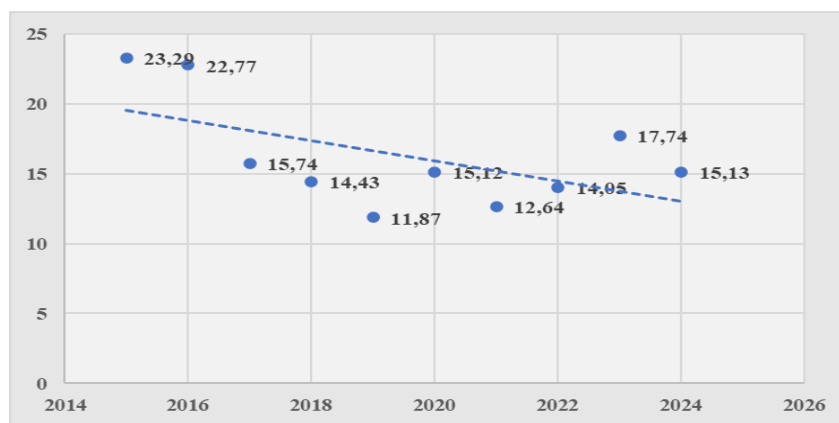


Figure 2 The declining trend line of coverage of AQ monitoring (%)

As shown in the following table, pollutants measured in 2024 in front of educational facilities were distributed in the following frequency: SO₂/19, soot/20, NO₂/20, atmospheric deposition/13 and PM₁₀/7. Analyzing values of SO₂, NO₂ and soot, being measured daily, no exceedances of the annual limit value were recorded for any of these parameters at the measuring points close to educational facilities (Table 2).

Measured at 21/185 sampling points, (11.35%) SO₂, soot, NO₂, are monitored mostly on regular basis, in daily measurements, while PM₁₀ is often monitored as part of indicative monitoring practice. Atmospheric deposition in front of educational institutions was monitored at 12 out of 185 measuring points in 2024, which is cca 6.5% (6.48%). Only at two points, in Vranje and Vranjska Banja, the mean annual concentration has exceeded the given limit value of 200 mg/m²/day. At only 6 out of all 185 measuring points in the survey had monitoring of PM₁₀ particles in front of educational facilities. In neither of cases did PM₁₀ concentration values were beyond the average annual limit value of 40 µg/m³.

Table 2 SO₂, soot, NO₂, PM₁₀ (µg/m³) and atmospheric deposition (AD)

Parameters	SO ₂	Soot	NO ₂	PM ₁₀	AD
	(µg/m ³)			mg/m ² /day	
Educational facilities					
Primary schools (15)					
„Nikola Tesla”, Rakovica	<10	6.50	21.75		
“Jefimija”, Obrenovac	13.50	5.30	12.75	30.83	98.83
"Milena Pavlović Barili", Višnjica	<10	6.10	13,83		
"Sestre Ilić", Valjevo	11.12	11.40	13.90		
„Svetozar Marković”, Vranje	25.20	17.30	15.50		216.52
“J.Jovanović Zmaj”, Vranje	26.80	10.83	16.27		120.17
“P.Devedić”, Vranjska Banja	16.38	7.27	7.12		217.23
“Vuk Karadzic”, Zvečan	4.12	6.05	0.70		
"M. Jovanović”, Kragujevac	3.00	36.33	17.33	33.25	
“St.Sremčević”, Kragujevac	3.33	28.00	17.92		
Kosjerić					102.20
Vranovo				44,20	
“Sonja Marinković”, Subotica				34.90	
"Đura Jakšić", Kać	6.38	13.08	17.70	24.80	
„Kralj Aleksandar I”, Požarevac	22.63	8.75	27.74		165.40
Kindergartens (11)					
„Pčelica” Valjevo	11	18.70	13.18		
„Kolibri”, Novo Valjevo	11	15.46	14.72		
"Vidra", Valjevo	11	14.63	12.80		
"Bubamara", Podgorska bb, Valjevo	11	14.10	33.63		
“Neven”, Vranje	26.97	10.38	23.47		99.42
Zvečan					124.71
Leposavić					113.85
Lešak					122.96
Zubin Potok					111.75
“Kolibri”, Leskovac	<5.00	20.70	8.10		
“Kolibri”, Kula				23.90	
High schools (3) + 1*					
Medical School, Kragujevac		18.50	27.25		
Medical School, Leskovac	<5.00	27.30	11.80		85.86
Economics HS, Srem.Mitrovica	3.30	15.50	19.06		
SOS Children’s village *	8.41		16.52	19.80	
Annual limit values	50	50	40	40	200

In most cases educational facilities are located at important city intersections, which is justified by choosing traffic-induced pollutants, such as SO₂, NO₂ and soot to be measured on daily basis [5–7]. On the other hand there is a significant disparity between the need to monitor the exposure of children to extremely high values of SO₂ [8,9] and unnecessary monitoring of atmospheric deposition, in which increased values of any parameter are regularly not recorded [4]. Through more rational allocation of resources, some better distribution of measuring stations and determining of parameters to monitor according to continuous air pollution sources, a more valuable assessment of the exposure to air pollution of vulnerable population groups (children from preschool to adolescence age), could be made. For example, the town of Bor and Krivelj village have a long history of environmental pollution due to copper mining and smelting activities, and AQ monitoring is covered with a substantial number of stations and parameters [10,11]. But, besides being an industrial town,

we have children living there, attending institutions of all levels of education (5 primary schools, kindergartens, a high school and University of Technology in Bor) in which they are exposed to pollutants entering from outdoor to indoor space, being well documented through literature [12,13]. Results of the APHEKOM network study indicate that near-road-related pollution may be responsible for a significant portion of the burden of asthma in children, as well as chronic heart diseases, in adults [13,14].

CONCLUSION

After having an insight into the frequency and choice of monitoring air quality at the local level in Serbia, a conclusion is imposed on an existing strong need to make indicator corrections in AQ monitoring in industrially contaminated urban settlements in Serbia and impose continuous monitoring in front of more schools and kindergartens in Bor, Smederevo, Pančevo, Šabac, as well as determining parameters depending on the source of emissions [4, 15–17].

REFERENCES

- [1] Wolfe, M.K., McDonald, N.C., Arunachalam, S., *et al.* J Urban Aff. 2020, 7, 43(8):10.1080/07352166.2020.1734013.
- [2] INCA (2009). INCA Comparative Tables (Online). International Review of Curriculum and Assessment Framework Internet Archive (INCA), London, UK.
- [3] Institute of Public Health of Serbia; Reports, Center of Hygiene and Human Ecology; Available from: <https://www.batut.org.rs/index.php?content=1413>.
- [4] Vujić, B.B., *et al.* Therm. Sci.. 2019, 23(6B), 4055–4065.
- [5] World Health Organization. Health effects of transport-related air pollution ISBN 92-890-1373-7; 2005.
- [6] Fuller, G., Anderson, R., Atkinson, R., *et al.* Air Qual. Atmos. Health. 2014, 7(4), 459–466.
- [7] Simonovski A., Tasić V., Apostolovski-Trijić T., Milikić N., Božilov A. ACTA UNIVERSITATIS Series: Working and Living Environmental Protection, 2020, 17(2), 131–137.
- [8] Nikolić, Dj., Milošević, N., Mihajlović, I. *et al.* Water Air Soil Pollut 2010, 206, 369–383.
- [9] Stanojević, A.B. Ann Environ Sci Toxicol 2021, 5(1), 023–026.
- [10] Tasić, V., Milošević, N., Kovačević, R., *et al.* Chem. Ind. Chem. Eng. Q. 2012, 18(4), 643–652.
- [11] Janssen, N.A.H., van Vliet, P.H.N., Aarts, F. *et al.* Atmos. Environ. 2021, 35, 3875–3884.
- [12] Perez L., Declercq C., Iñiguez C., Eur Respir J 2013, 42,: 594–605.
- [13] Martin R., Dowling K., Pearce D., *et al.* Geosciences 2014, 4, 128–175,
- [14] Kovačević R., Jovašević-Stojanović M., Tasić V., *et al.* Chem. Ind. Chem. Eng. Q. 2010, 16(3), 269–279.
- [15] Bergstra, A., Brunekreef B., Burdorf, Environ. Health. (2018) 17(30).
- [16] Rovira, E., Cuadras, A., Aguilar, X., *et al.*, Environ. Res, 2014, 133, 156–163.
- [17] Matić, B.I., Rakić, U.D., Dejanović S.M., *et al.* TEHNIKA – KVALITET IMS, STANDARDIZACIJA I METROLOGIJA, 2017, 17(3), 441–447.