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MASS CONCENTRATIONS AND INDOOR--OUTDOOR RELATIONSHIPS OF PM IN SELECTED EDUCATIONAL BUILDINGS IN NIŠ, SERBIA*

Article Highlights

- The daily average PM_{10} concentrations exceeded the EU limit value during 34-35% of days outdoors
- The daily average PM_{10} concentrations exceeded the EU limit value during 39-53% of days indoors
- The daily average $PM_{2.5}$ concentrations exceeded the WHO guideline value during 71% of days outdoors
- The daily average $PM_{2.5}$ concentrations exceeded the WHO guideline value during 88% of days indoors
- The average PM_{10} I/O ratio at VK was 1.57 during teaching hours, and 1.00 during no teaching hours

Abstract

Mass concentrations of particulate matter (PM) fractions were measured in educational buildings in the city of Niš, Serbia. Two sampling campaigns were conducted in winter periods. The first campaign was in the period from 21 February to 15 April 2010 at the Faculty of Occupational Safety (FOS) and the second campaign was from 20 March to 4 April 2013 at the primary school Vožd Karađorđe (VK). PM measurements were carried out with low volume samplers Sven/Leckel LVS3. The average daily PM_{10} concentration inside the FOS (47.0±21.8 μg/m^3) was lower than PM_{10} concentration in outdoor air (50.7±28.1 μg/m^3). The average daily PM_{10} concentration inside the VK (54.6±±17.6 μg/m^3) was higher than in outdoor air (47.9±22.8 μg/m^3). The 24-hours average PM_{10} concentrations at FOS exceeded the EU limit value (50 μg/m^3) during 34% of days outdoors and 39% of days indoors. The 24-hours average PM_{10} concentrations at VK exceeded the limit value during 35% of days outdoors and 53% of days indoors. The 24-hours average $PM_{2.5}$ concentrations at VK exceeded the WHO daily mean guideline value (25 μg/m^3) during 71% of days outdoors and 88% of days indoors. The average PM_{10} I/O ratio at VK was 1.57 during teaching hours, and 1.00 during no teaching hours. Similarly, average $PM_{2.5}$ I/O ratio at VK was 1.11 during teaching hours and 0.90 during no teaching hours. Average daily $PM_{2.5}/PM_{10}$ ratio in the ambient air at VK was 0.87, and 0.82 at FOS. Very strong correlations between the indoor and outdoor PM concentrations were observed at VK during no teaching hours ($r > 0.8$). Moderate to strong negative correlations were found between the wind speed and PM at both schools. High outdoor PM concentrations and resuspension of particles are possible reasons for the elevated indoor PM concentrations found in the study.

Keywords: urban air quality, indoor air pollution, particulate matter, gravimetric, correlation, school.

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The relationships between outdoor air pollution and health are beyond doubt [1-4]. In the aim of human health protection, the EU has introduced limit values for PM_{10} and $PM_{2.5}$ concentrations in the ambient air. Limit values for PM_{10} were included in the Council Directive 1999/30/EC, later amended by the Council Directive 2008/50/EC, which prescribed a daily limit value of 50 $\mu g/m^3$ not to be exceeded more than 35 times per calendar year, and an annual limit value of 40 $\mu g/m^3$. The Council Directive 2008/50/EC established also $PM_{2.5}$ thresholds in the ambient air. The annual average $PM_{2.5}$ concentration cannot exceed 25 $\mu g/m^3$ by 2015. The influence of indoor air pollution on health is complex and still unexplored in detail so receives more attention of researchers at the moment. In the indoor environment, in which people spend most of their time, both indoor and outdoor sources contribute to PM concentrations [5]. The indoor environment is legislatively a difficult one due to the many public and private actors involved [6]. In addition, information about indoor air quality is generally lacking, and there are almost no systematic monitoring programs.

In accordance with the Air Protection Law [7], the Serbian Environmental Protection Agency (SEPA) has authority over the national network for air quality monitoring in the Republic of Serbia. SEPA nowadays operates the network with 40 automatic monitoring stations (AMS) included. Two of them (AMS Nis Traffic, and AMS Nis Urban) were installed in the city of Niš in 2009. The AMS Nis Traffic is situated in the city center, in a residential area, near a major avenue with heavy-traffic. This AMS contains GRIMM EDM 180 dust monitor, for real-time monitoring of PM_{10} and $PM_{2.5}$ concentrations. According to SEPA annual report for 2010, the annual mean concentration of PM_{10} in Niš was 51 $\mu g/m^3$ (123 days with PM_{10} concentrations over daily limit of 50 $\mu g/m^3$) that is among the highest PM_{10} concentrations identified over urban areas in the Republic of Serbia in 2010 [8]. The annual mean PM_{10} concentrations in ambient air in Niš were in the upper side of the bandwidth, but thoroughly comparable to concentrations monitored at various sites throughout Europe [9-11]. According to SEPA reports, in the Niš city center the dominant sources of air pollution were traffic and fossil fuel combustion for heating the dwellings [8]. As sulfur dioxide (SO_2) in ambient air originates from fossil fuel combustion and nitrogen oxide (NO_2) also originates from emissions from cars, trucks and buses, we tried to find their relationship with PM concentrations near sampling sites. For that purpose, Pearson's correlation coefficients between PM, SO_2 and NO_2 concentrations and meteorological parameters were determined. In our analyses we used meteorological data and SO_2 and NO_2 concentrations (daily averages) from the AMS Niš Traffic.

Indoor air quality in educational buildings is of the greatest importance since children and students spend a large part of their time in classrooms. In the references [12,13] simultaneous measurements of the indoor and outdoor particle mass concentrations have been conducted in 6 occupied and unoccupied classrooms in 3 secondary schools in Lublin, Poland, in the heating and summer seasons. The particle exposures experienced by students were higher in the monitored classrooms than outdoors. In the winter season the average student exposure to PM_{10} was 2.16±0.52 times higher than outdoors, while exposure to $PM_{2.5}$ was 1.55±0.52 times higher than outdoors. Significant correlation between the PM concentrations during the winter was assumed to be caused by the resuspension of the particles that were generated during the outdoor combustion processes and deposited in the classrooms. Based on the measurements performed in duration of 6 weeks, in two classrooms in one primary school in Munich during winter season, Fromme *et al.* [14] reported the median PM_{10} concentration of 118.2 $\mu g/m^3$ and $PM_{2.5}$ concentration of 37.4 $\mu g/m^3$ indoors. The corresponding results for the outdoor air were 24.2 and 17.0 $\mu g/m^3$. It was noted that physical activity of the pupils leads to resuspension of indoor coarse particles and greatly contributes to increase PM_{10} in classrooms. It was also considered that the PM measured in classrooms has major sources other than outdoor particles, so that indoor-generated PM may be less toxic compared to PM in ambient air [14]. Guo *et al.* [15] investigated indoor and outdoor $PM_{2.5}$ mass concentrations during winter season in primary school in Brisbane, Australia. It was found that indoor $PM_{2.5}$ level was mainly affected by the outdoor $PM_{2.5}$ level (r = 0.68, $p <$ < 0.01). No significant difference in I/O ratios for $PM_{2.5}$ was observed between occupied and unoccupied classrooms.

A European Observatory on Indoor Air SINPHONIE project [16] had developed a monitoring framework and collected data for assessment of health related aspects of European schools. Also, several project concerning to air pollution in schools were carried out or in progress in the Republic of Serbia [6]. Unfortunately, still there is not enough information about indoor air quality in schools in the Republic of Serbia. The relationship between the air pollution inside and outside the schools is also insufficiently known. The aim of this study was to present the first results of an ongoing study on schoolchildren and student exposure to PM in the Niš city center.

EXPERIMENTAL

The city of Niš is located at the crossroads of the Balkans to Europe, and Europe to the Near East, as shown in Figure 1. It is the center of the Southeastern Region of Serbia and the second biggest city in the Republic of Serbia with about 350,000 inhabitants. The city area is in the valley closed from three sides, at height of 194 m above sea level. Niš has a moderate continental climate with average annual temperature of about 11.2 °C. Temperature inversions are frequent during cold period of year (October-April). Mist and fog are present for more than 100 days a year [17]. Air pollution monitoring in Niš started in 1965 at two monitoring sites by measuring daily concentrations of sulphur dioxide, black smoke and deposited dust particles. From that period, the number of monitoring sites and parameters has significantly increased so that today 15 pollutants are being monitored at ten monitoring sites. The dominant sources of air pollution are transportation, local heating and industry [17].

Two measurement campaigns were conducted in two educational buildings in the Niš city center. The first campaign was conducted from 21 February to 15 April 2010, at Faculty of Occupational Safety (FOS), urban-residential site. The second campaign was conducted from 20 March to 4 April 2013 at primary school Vožd Karađorđe (VK), on a busy street, urban-traffic site. We chose schools located in the city center because of the heavy traffic with the aim of providing the better insight on the influence of outdoor to indoor PM pollution in the selected schools. The indoor and outdoor measurements of PM fractions were carried out in parallel. European reference low volume samplers, LVS3 (Sven/Leckel LVS3) with size-selective inlets for PM_{10} and $PM_{2.5}$ fractions, were used to collect particulate matter. PM concentrations were obtained from gravimetric analysis of filters and sample volume, which is logged by the sampler throughout the sampling period. The LVS3 sampler flow rate (2.3 m^3/h) was calibrated using the certified flow meter just before the measurement campaign. Averaging time was 24 h for both the indoor and outdoor measurements at FOS. At VK averaging time was 12 h (from 8 AM to 8 PM – teaching hours, and from 8 PM to 8 AM – no teaching hours).

Quartz fiber filters (Whatman QMA, 47 mm diameter) were used throughout this study. Pre-conditioning and post-conditioning of filters was undertaken in accordance with the general requirements of SRPS EN 12341:2008 [18]. Approximately 15% of all gravimetric samples were collected as field blanks. After preconditioning in a clean room, filters were weighing using the Mettler Toledo semi-micro balance (with min. 10 µg mass resolution). PM con-

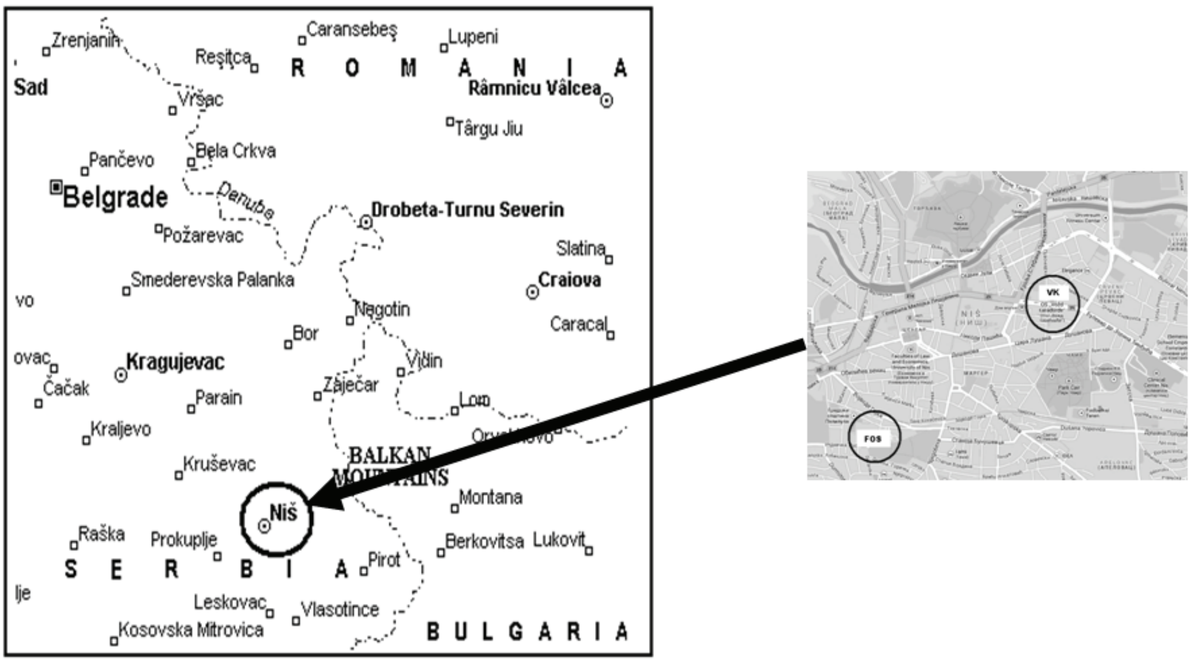

Figure 1. Map of Serbia and the city center of Niš with marked sampling sites (FOS and VK).

centrations were calculated using average (each filter is measured three times) weight of filters. Average change in the field blank weight (FOS - 3.1 µg, VK - 2.5 µg) was subtracted from net mass of the sample filters. The detection limit (FOS - 3.5 µg/m^3, VK - 2.7 µg/m^3) was calculated as three times the standard deviation in net mass of the field blanks divided by the nominal sample volume. Indoor samples were taken at ground floor (FOS samples were taken in the amphitheater with a floor space of 100 m^2 and a volume of 300 m^3. The amphitheater was occupied by 40-50 students during teaching hours, VK samples were taken in the hallway with a floor space of 60 m^2 and a volume of 200 m^3. The hallway was occupied with an average of 80 pupils during the breaks between classes, while ambient air was sampled on the balconies about 10 m above the ground. There were no additional ventilation systems in FOS and VK buildings. In the heating period (October-April) both schools used district heating system. In our analyses we have used SO_2 and NO_2 concentrations and meteorological parameters (daily averages) from the AMS Traffic Niš in order to determine the interdependence with PM concentrations. This AMS is situated in the city center, in the same avenue as VK (0.5 km east) and about 2 km east from FOS.

RESULTS AND DISCUSSION

Mass concentrations

The average daily PM_{10} and $PM_{2.5}$ concentrations, ranges and indoor/outdoor (I/O) ratios are summarized in Table 1. There is no significant difference between average daily PM_{10} concentrations indoor and outdoor (at the level 0.05), although average daily PM_{10} concentration found inside the FOS (47.0±21.8 µg/m^3) were lower than in outdoor air (50.7±28.1 µg/m^3). The daily PM_{10} concentrations at FOS exceeded the EU limit value (50 µg/m^3) during 34% of days outdoors and 39% of days indoors. The average of daily PM_{10} concentrations found inside the VK (54.6 ± 17.6 µg/m^3) was significantly higher than in outdoor air (47.9±22.8 µg/m^3). The average of daily PM_{10} concentrations at VK exceeded the limit value during 35% of days outdoors and 53% of days indoors.

Due to a sampler failure at FOS in the beginning of campaign, the indoor $PM_{2.5}$ concentrations were presented only for VK. The average daily $PM_{2.5}$ concentration found inside the VK (38.5 µg/m^3±13.8 µg/m^3) was lower than in outdoor air (40.8 µg/m^3±18.9 µg/m^3). The daily $PM_{2.5}$ concentrations at VK exceeded the WHO daily mean guideline value (25 µg/m^3) [19] during 71% of days outdoors and 88% of days indoors.

In the recent years, several studies about air pollution with PM in school environment have been published. PM concentrations obtained in some studies similar to our study were shown in Table 2. According to Table 2 our results were in line with results of the studies published previous that was carried out in schools in the different regions of the world. The PM_{10} concentration levels that were detected inside the VK during no teaching hours confirmed that no specific sources of PM pollution existed in the school (as shown in Figures 2 and 3). Thus, it seem that high indoor concentrations of PM_{10} found in VK during teaching hours could be linked to resuspension as well as to generation of the particles caused by the presence of pupils in the school.

PM relationships

The I/O ratio of PM concentration is often used to justify the presence of indoor sources (*I/O* >1) or infiltration of ambient air (*I/O* ≤ 1) [20, 21]. According to Table 1, average of daily I/O ratios for PM_{10} concentrations was 1.01 at FOS and 1.25 at VK. Average of daily I/O ratios for $PM_{2.5}$ concentrations was 1.01 at

Table 1. Statistics of average daily PM_{10} and $PM_{2.5}$ concentrations and average daily I/O ratios at FOS and VK (SD - standard deviation, n - number of days)

PM fraction	Sampling site	Indoor			Outdoor			*I/O*	*n*
		Average	Range	*SD*	Average	Range	*SD*		
		µg/m^3	µg/m^3		µg/m^3	µg/m^3			
PM_{10}	FOS	47.0	10.3-95.4	21.8	50.7	13.7-113.7	28.1	1.01	49
	VK	54.6	26.1-91.9	17.6	49.7	20.0-88.0	23.2	1.25	17
$PM_{2.5}$	FOS	-	-	-	42.5	10.3-103.5	24.8	-	49
	VK	38.5	15.3-68.6	13.8	40.3	18.2-85.5	18.9	1.01	17
PM_{10}	VK, 8 AM to 8 PM	63.1	26.1-91.4	15.8	44.5	24.1-86.0	18.1	1.57	17
	VK, 8 PM to 8 AM	47.3	15.9-102.8	23.7	50.6	12.7-118.0	29.6	1.00	17
$PM_{2.5}$	VK, 8 AM to 8 PM	40.3	15.3-63.5	11.3	40.8	18.8-110.7	22.9	1.11	17
	VK, 8 PM to 8 AM	36.1	12.2-85.0	18.4	42.1	10.9-104.7	23.7	0.90	17

Table 2. Average daily PM concentrations and ranges (μg/m^3) from some previous studies

Location	PM_{10}		$PM_{2.5}$		Number of schools	Season	Reference
	Indoor	Outdoor	Indoor	Outdoor			
Aveiro, Portugal	49.2	23.4	-	-	1	Spring	Pegas et al. [20]
Thessalonica, Greece	118	-	91	-	1	-	Gemenetzis et al. [21]
London, England	80	-	30	-	-	-	Wheeler et al. [22]
Munich, Germany	105.0	-	38.9	-	64	Winter	Fromme et al. [23]
Athens, Greece	229	166	82	56	7	Winter	Diapouli et al. [24]
Hong Kong China	80-230	80-200	-	-	5	Winter	Lee and Chang et al. [25]
Istanbul, Turkey	27.9-289.0	-	13.3-95.2	-	5	Spring	Ekmekcioglu and Keskin [26]
Netherlands	-	-	7.7-52.8	5.2-60.8	24	1 Year	Janssen et al. [27]
Stockholm, Sweden	-	-	2.8-13.9	5.2-24.2	6	-	Wichmann et al. [28]

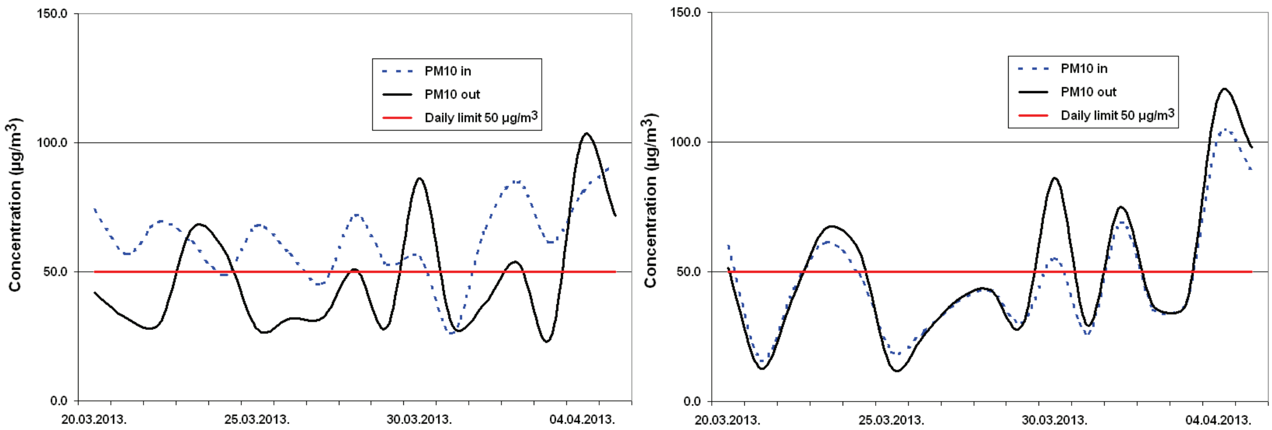

Figure 2. PM_{10} concentrations at VK during teaching hours (left) and during no teaching hours (right).

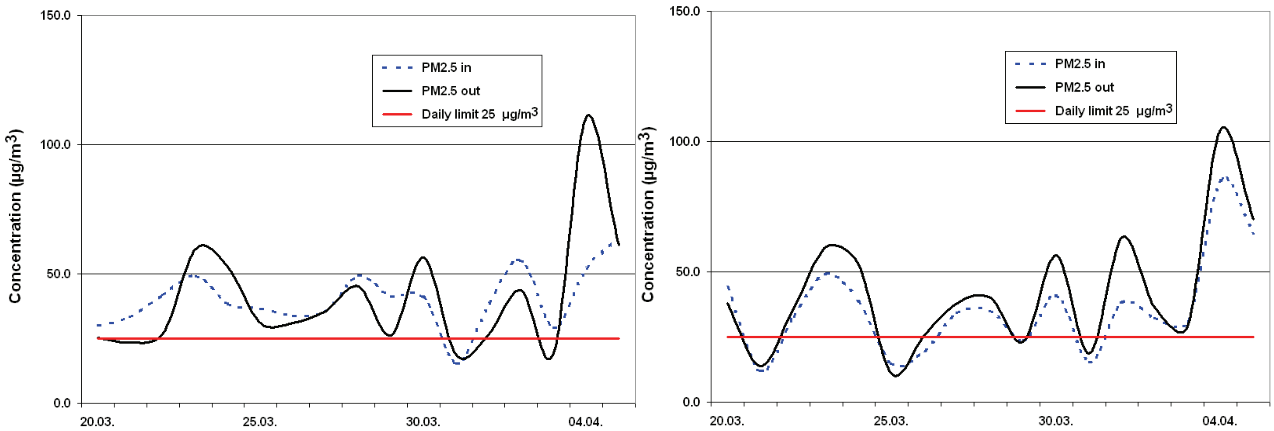

Figure 3. $PM_{2.5}$ concentrations at VK during teaching hours (left) and during no teaching hours (right).

VK. According to Table 1, average PM_{10} and $PM_{2.5}$ concentrations, ranges, and I/O ratios at VK were different during teaching hours (8 AM to 8 PM) than during no teaching hours (8 PM to 8 AM). The average PM_{10} I/O ratio was 1.57 during teaching hours and 1.00 during no teaching hours. These findings are consistent with the results obtained for seven primary schools in Athens that has a similar PM_{10} I/O concentrations ratio (1.65) [11]. Average $PM_{2.5}$ I/O ratio during teaching hours at VK was 1.11 and 0.90 during no teaching hours. By omitting weekends from the analysis, situation worsens concerning the indoor PM concentrations. In that case, average PM_{10} I/O ratio during teaching hours at VK rises to 1.80 and to 1.05 during no teaching hours. Similarly, in such case, average $PM_{2.5}$ I/O ratio during teaching hours at

VK rises to 1.22 and to 0.94 during no teaching hours. The average of daily $PM_{2.5}$ I/O ratios found at VK during winter is similar to that found in the primary schools in Stockholm (0.94) [28].

Pearson correlation coefficients between PM concentrations at VK and FOS are presented in Table 3. Strong correlations ($0.8 > r > 0.6$) between indoor and outdoor PM_{10} concentrations were found at FOS, with the exceptions of very strong correlation ($r > 0.8$) between PM_{10} indoor and $PM_{2.5}$ outdoor concentrations (0.89) [29]. Very strong correlation between indoor and outdoor PM concentrations during no teaching hours was observed at VK. In contrast, strong correlation between indoor and outdoor PM concentrations during teaching hours were observed at VK, with the exceptions of moderate correlation ($0.6 > r > 0.4$) between the PM_{10} indoor and $PM_{2.5}$ outdoor concentrations ($r = 0.43$).

Relationships between PM, NO_2, SO_2 and meteorological parameters

Basic statistics for some meteorological parameters, SO_2 and NO_2 concentrations, during the measurements campaigns, was calculated based on data taken from the AMS Nis Traffic. The average values of meteorological parameters were very similar in both measurement periods (wind speed 1.1 m/s, atmospheric pressure 992-994 mbar, temperature 7-8 °C and relative humidity 67-75%). The average values of SO_2 and NO_2 concentrations were very similar also (average SO_2 concentration during the first campaign was 20.5 and 19.5 μg/m^3 in second campaign, average NO_2 concentration during the first campaign was 40.5 and 38.5 μg/m^3 in second campaign). Pearson correlation coefficients between the selected meteorological parameters, PM, SO_2 and NO_2 concentrations are shown in Table 4. For clarity purposes,

Table 3. Pearson correlation coefficients between the average daily PM concentrations at VK and FOS

Sampling site		$PM_{10\ OUTDOOR}$	$PM_{2.5\ OUTDOOR}$	$PM_{10\ INDOOR}$	$PM_{2.5\ INDOOR}$
VK - Teaching hours	$PM_{10\ OUTDOOR}$	1			
	$PM_{2.5\ OUTDOOR}$	0.65	1		
	$PM_{10\ INDOOR}$	**0.82**	0.43	1	
	$PM_{2.5\ INDOOR}$	0.61	0.66	0.79	1
VK - No teaching hours	$PM_{10\ OUTDOOR}$	1			
	$PM_{2.5\ OUTDOOR}$	**0.97**	1		
	$PM_{10\ INDOOR}$	**0.99**	**0.96**	1	
	$PM_{2.5\ INDOOR}$	**0.93**	**0.96**	**0.97**	1
FOS - Daily averages	$PM_{10\ OUTDOOR}$	1			
	$PM_{2.5\ OUTDOOR}$	**0.89**	1		
	$PM_{10\ INDOOR}$	0.72	0.71	1	

Table 4. Pearson correlation coefficients between average daily PM, SO_2 and NO_2 concentrations and meteo parameters: wind speed (WS), atmospheric pressure (P), temperature (T) and relative humidity (RH)

Sampling site		$PM_{10\ OUTDOOR}$	$PM_{2.5\ OUTDOOR}$	$SO_{2\ OUTDOOR}$	$NO_{2\ OUTDOOR}$	WS	P	T	RH
FOS	$PM_{10\ OUTDOOR}$	1							
	$PM_{2.5\ OUTDOOR}$	**0.89**	1						
	$SO_{2\ OUTDOOR}$	**0.53**	**0.56**	1					
	$NO_{2\ OUTDOOR}$	**0.53**	**0.54**	**0.59**	1				
	WS	**-0.59**	**-0.56**	-0.13	**-0.51**	1			
	P	0.39	0.38	0.33	0.08	-0.02	1		
	T	0.13	0.01	0.11	0.12	-0.31	0.09	1	
	RH	-0.28	-0.18	-0.21	0.01	-0.04	-0.47	-0.39	1
VK	$PM_{10\ OUTDOOR}$	1							
	$PM_{2.5\ OUTDOOR}$	**0.90**	1						
	$SO_{2\ OUTDOOR}$	**0.63**	**0.52**	1					
	$NO_{2\ OUTDOOR}$	**0.63**	**0.53**	**0.50**	1				
	WS	**-0.63**	**-0.57**	-0.35	**-0.69**	1			
	P	0.33	0.39	0.23	0.27	-0.33	1		
	T	0.29	0.03	0.25	0.09	-0.14	-0.36	1	
	RH	-0.18	0.02	-0.36	0.07	-0.05	-0.27	-0.35	1

daily average concentrations for some parameters are presented in Figures 5 and 6.

Moderate negative correlation between WS and PM and between WS and NO_2 indicate that increase of wind speed improves dispersion of these air pollutants at FOS. Figures 5 and 6 clearly show this phenomenon. Correlation between PM concentrations and P, T and RH is weak ($0.4 > r > 0.2$) or very weak ($0.2 > r$) at FOS. A strong negative correlation between WS and PM_{10}, and between WS and NO_2 was observed at VK. A moderate correlation between WS and $PM_{2.5}$, SO_2 and NO_2 was observed at VK. Correlations between PM and P, T and RH were weak or very weak at VK. Changes in NO_2, SO_2 and PM_{10} concentrations at both sampling locations had identical trend in almost the whole period of measurement. A similar relationship between the air pollutant concentrations and changes of wind speed is also noticed in the Bor town [30].

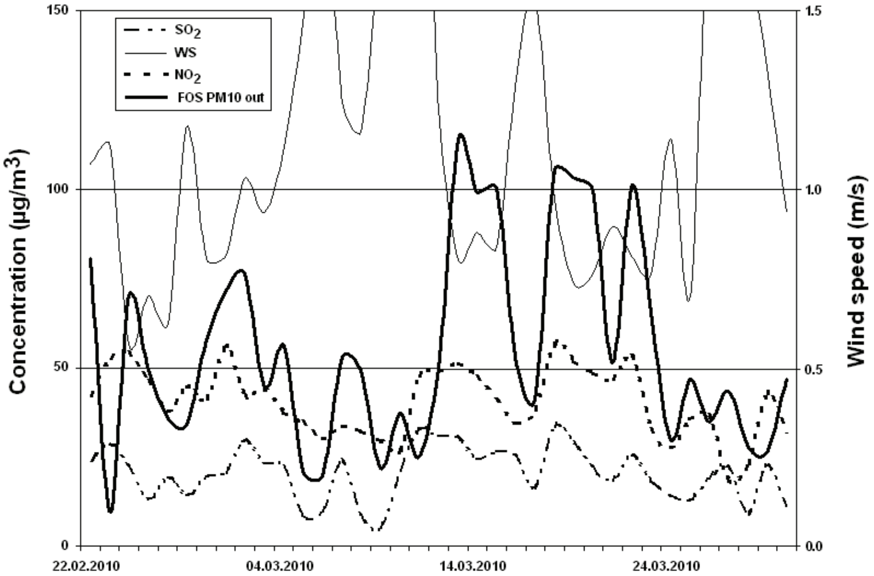

Figure 5. Outdoor PM_{10} concentrations at FOS, together with wind speed (WS), SO_2 and NO_2 concentrations at AMS Niš Traffic (daily averages).

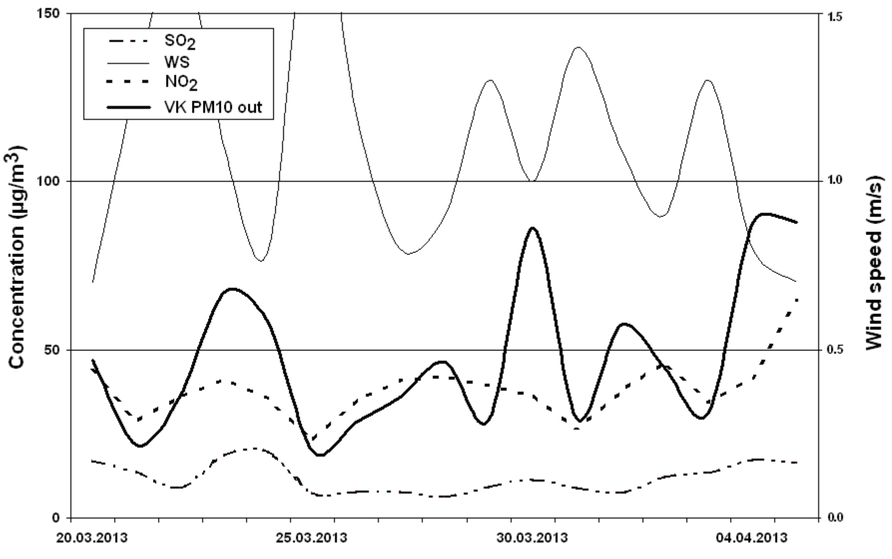

Figure 6. Outdoor PM_{10} concentrations at VK, together with wind speed (WS), SO_2 and NO_2 concentrations at AMS Niš Traffic (daily averages).

CONCLUSION

This work presents one of the first attempts to examine the impact of PM concentrations from ambient air to PM concentrations inside the school buildings in the Niš city center. High PM concentrations together with a majority of days with PM concentrations over limits were observed in both indoor and outdoor environments. It is observed that wind speed is the most important meteorological parameter for dispersion of air pollutants in winter in the Niš city center. High outdoor PM concentrations, limited ventilation in schools during winter, and resuspension of particles are the most probable reasons for the elevated indoor PM concentrations found in the present study. Thus, the observed school environments in the Niš city center offer low protection against the combustion-related particles originated from outdoor air. The appropriate measures should be prescribed with the aim to provide better air quality inside schools in the city of Niš. Further research should be continued in the summer period in order to determine whether there are seasonal changes in the concentrations of PM and how they influence the PM I/O relationship.

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NAUČNI RAD

KONCENTRACIJA SUSPENDOVANIH ČESTICA (PM_{10} I $PM_{2.5}$) I NJIHOV ODNOS UNUTRA/SPOLJA U ODABRANIM OBRAZOVNIM USTANOVAMA U NIŠU

U radu su prikazani rezultati merenja suspendovanih čestica frakcija PM_{10} i $PM_{2.5}$ u dve izabrane obrazovne ustanove u Nišu. Kampanje merenja sprovedene su u zimskom periodu. Prva u periodu od 21.02. do 15.04.2010. na Fakultetu zaštite na radu (FOS), a druga u periodu od 20.03. do 04.04.2013. u osnovnoj školi Vožd Karađorđe (VK). Uzorkovanje suspendovanih čestica vršeno je uzorkivačima Sven/Leckel LVS3, simultano, unutar i izvan odabranih ustanova. Prosečna dnevna koncentracija čestica PM_{10} unutar objekta FOS (47,0±21,8 μg/m^3) bila je niža u odnosu na prosečnu dnevnu koncentraciju PM_{10} u ambijentalnom vazduhu (50,7±28,1 μg/m^3). Prosečna dnevna koncentracija čestica PM_{10} unutar objekta VK (54.6±17.6 μg/m^3) bila je viša u odnosu na prosečnu dnevnu koncentraciju PM_{10} u ambijentalnom vazduhu (47.9±22.8 μg/m^3). Srednje dnevne koncentracije čestica PM_{10} izmerene na lokaciji FOS u ambijentalnom vazduhu prelazile su dnevnu graničnu vrednost (50 μg/m^3) tokom 34% dana trajanja kampanje merenja. Srednje dnevne koncentracije čestica PM_{10} izmerene unutar objekta FOS prelazile su dnevnu graničnu vrednost tokom 39% dana trajanja kampanje merenja. Srednje dnevne koncentracije čestica PM_{10} izmerene na lokaciji VK u ambijentalnom vazduhu prelazile su dnevnu graničnu vrednost tokom 35% dana trajanja kampanje merenja, odnosno tokom 53% dana trajanja kampanje u unutrašnjosti objekta VK. Srednje dnevne koncentracije čestica $PM_{2,5}$ izmerene na lokaciji VK u ambijentalnom vazduhu prelazile su dnevnu graničnu vrednost (25 μg/m^3) tokom 71% dana trajanja kampanje, odnosno tokom 88% dana u unutrašnjosti objekta VK. Prosečan dnevni odnos unutra/spolja čestica frakcije PM_{10} na lokaciji VK iznosio je 1,57 u vreme nastave, odnosno 1,00 kada nije bilo nastave. Prosečan dnevni odnos unutra/spolja čestica frakcije $PM_{2,5}$ na lokaciji VK iznosio je 1.11 u vreme nastave, odnosno 0.90 kada nije bilo nastave. Prosečan dnevni odnos $PM_{2,5}/PM_{10}$ u ambijentalnom vazduhu na lokaciji VK bio je 0,87, odnosno 0,82 na lokaciji FOS. Detektovana je veoma jaka korelacija između koncentracija suspendovanih čestica unutar i izvan objekta VK u periodu kada nije bilo nastave ($r > 0.8$). Umerena do jaka korelacija detektovana je između brzine vetra i koncentracija suspendovanih čestica na obe lokacije (FOS i VK). Visoke koncentracije suspendovanih čestica u ambijentalnom vazduhu i resuspenzija čestica najverovatniji su razlog koji utiče na povećane koncentracije suspendovanih čestica u unutrašnjem prostoru posmatranih obrazovnih ustanova.

Ključne reči: kvalitet vazduha, zagađenje vazduha, suspendovane čestice, gravimetrija, korelacija, škole.