Global Alliance against Chronic Respiratory Diseases demonstration project: aerosol pollution and its seasonal peculiarities in primary schools of Vilnius

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Abstract

Background: The growing public health concern caused by non-communicable diseases in urban surroundings cannot be solved by health care alone; therefore a multidisciplinary approach is mandatory. This study aimed to evaluate the airborne aerosol pollution level in primary schools as possible factor influencing origin and course of the diseases in children.

Methods: Seasonal aerosol particle number concentration (PNC) and mass concentration (PMC) were studied in the randomly selected eleven primary schools in the Lithuanian capital, Vilnius, as model of a middle-size Eastern European city. Total PNC in the size range from 0.01 to >1.0 μm in diameter was measured using a condensation particle counter. Using an optical particle sizer, PNC was measured and PMC estimated for particles from 0.3 to 10.0 μm. A descriptive statistics was used to estimate the aerosol pollution levels.

Results: During all seasons, local cafeterias in the absence of ventilation were the main sources of the elevated levels of indoor PMC and PNC (up to 97,500 particles/cm^3). The other sources of airborne particulates were the children's activity during the lesson breaks with PMC up to 586 μg/m^3. Soft furniture, carpets in the classrooms and corridors were responsible for PMC up to 200 μg/m^3. Outdoor aerosol pollution (up to 18,170 particles/cm^3) was higher for schools in city center. Elevated air pollution in classrooms also resulted from intermittent sources, such as construction work during classes (200–1000 μg/m^3) and petrol-powered lawn trimmers (up to 66,400 particles/cm^3).

Conclusion: The results of our survey show that even in a relatively low polluted region of Eastern Europe there are big differences in aerosol pollution within middle-sized city. Additional efforts are needed to improve air quality in schools: more frequent wet cleaning, monitoring the operation of ventilation systems, a ban on construction works during school year, on a use of sandblasting mechanisms in the neighborhood of schools.

Keywords: Children; Indoor aerosol; Pollution levels; Primary school; Systematic and occasional sources; Ventilation

Introduction

Health promotion and prevention should start at conception and be continued across the life cycle for healthy lungs and active and healthy aging. They form the basis of the goals of the Europe 2020 strategy of healthy and active aging, the United Nations' Sustainable Development Goals for 2030, and the World Health Organization (WHO) strategy on non-communicable diseases (NCDs).[1,2] The growing public health concern caused by NCDs in urban surroundings must be solved in the frame of the multidisciplinary study, paying special attention to the air pollution levels.[3]

According to WHO, ambient particulate matter is responsible for an increased number of respiratory and

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cardiovascular diseases and deaths.[4,5] For each 10 μg/m^3 increase in particle mass concentrations (PMC) of particles less than or equal to 10 μm (PM_{10}), respiratory mortality increases by 3.4% and cardiovascular mortality increases by 1.4%.[6]

Taminskiene *et al*[7] emphasize that clinicians should be mindful not only of the impact of asthma on the child and the family, but also consider exploring factors not directly related to childhood asthma, including increased tension and anxiety in family, financial hardships, and the impaired balance of personal and professional life.

Children are more susceptible to air pollution than adults.[8,9] Franck *et al*[10] and Breitner *et al*[11] have shown that in assessing the impact on human health and respiratory diseases, sub-micron aerosol fraction (<1 μm) becomes more important, and both the mass and number concentrations should be considered. However, parallel studies of both aerosol number and mass concentrations in schools are scarce, especially those evaluating the influence of outdoor aerosol pollution affecting indoor air. Reports presenting the results of measurements of particle concentrations in schools have been recently published.[12,13,14,15] Blondeau *et al*,[12] studying indoor to outdoor ratios of nitrogen oxides, ozone and particle number (0.3–15.0 μm) concentrations in eight schools of La Rochelle, France, found that one of the main sources of indoor air pollution by coarse particles (size range from 2.5–10.0 μm in diameter) was their re-suspension due to the pupil activity.

The schools indoor pollution and health observatory network in Europe project showed that in many European countries air quality in schools is an urgent problem.[15] Fromme *et al*[13] also found a high exposure of pupils in schools to particulate matter and a correlation between carbon dioxide concentrations and indoor aerosol pollution in schools. Main outdoor sources of air pollution, such as traffic emissions and residential heating, also affect the air quality in schools.[16]

The aim of our survey was to evaluate the main seasonal aerosol pollution levels and its sources in primary schools of Lithuanian capital, Vilnius, with about 570,000 inhabitants, as model of middle-size Eastern European city. Seasonal indoor and outdoor aerosol particle number and mass concentrations were measured and estimated in Lithuania as a Global Alliance against Chronic Respiratory Diseases demonstration project.[1]

Methods

Sampling sites and school description

Vilnius, situated at 54°41′17″ N, 25°15′58″ E, is located between two rivers, the Neris and the Vilnia, in a heavily hilly area. We sent invitations to all 107 Vilnius schools to participate in the study, 25 of them agreed and every second of the list we included in the study. However, one of the selected schools did not have primary classes and was rejected. In this way, 11 schools were randomly selected to participate in the study. Selected schools were located in areas of different outdoor air pollution levels. Schools numbered 1, 5, 7, 10 were located in the downtown area; schools numbered 2, 3, 4, 6, and 8 were located in the peripheral part of the city and those numbered 9 and 11 were located in the suburbs [Figure 1].

Methodology

A condensation particle counter (CPC; TSI model 3007, total aerosol particle number concentration (PNC) in the size range of 0.01 to >1.0 μm) and an optical particle sizer (OPS, TSI model 3330, aerosol PNC and its distribution by sizes in the range of 0.3–10.0 μm) were used. PNC (CPC) is total PNC measured by CPC. PNC (OPS) and PMC (OPS) are PNC and PMC measured and evaluated by OPS, respectively.

The PMC was calculated by OPS software, with the predefined particle density of 1 g/cm^3. Before measurements, the instruments were checked for contamination by using high efficiency particulate arrestance filters.

The indoor aerosol pollution in the classrooms, corridors, and nearby cafeterias of the primary schools was measured. Because of the technical requirements of the CPC (air temperature – higher than 10°C and air humidity – below 70%), outdoor aerosol concentrations were measured in late autumn and winter usually for some (6–7) min in rooms in an induced draught. In spring, outdoor measurements were carried out near schools for 10 min. In the schools, indoor measurements were carried out during lessons from 9 until 14 h in four or five classrooms on different floors for 10 min each. The devices were placed on the last desk of the classroom. Indoor measurements were also carried out near the cafeterias and in the corridors during the lesson breaks. The data collection period lasted from the start of the heating season in October 2017 until May 2018. In autumn and winter, in each school, measurements were repeated twice, while in spring measurements were repeated up to three times.

Results

Systematic sources of indoor pollution

Typical data on aerosol pollution in school No. 3

A typical situation can be shown using measurements in autumn in school No. 3 located in the peripheral part of the city [Figures 2 and 3]. At this time, total PNC (CPC) and PMC (OPS) near the cafeteria (first floor) varied from 40,000 to 78,000 particles/cm^3 and from 100 to 140 μg/m^3, respectively. The cafeteria appeared to be responsible for high PNC values (up to 24,000 particles/cm^3) in the classrooms on the second and third floors of the building because of the air circulation. Low PNC values in the classrooms on the first floor were related to low outdoor PNC (about 9000 particles/cm^3). Apparently, in the classroom nearby the cafeteria, due to coarse aerosol settling after the lesson break, high PMC (OPS) values decreased during measurements from about 270 μg/m^3 after the lesson beginning down to about 150 μg/m^3. Main determinants of PMC were the pupils' activity during lesson breaks and ventilation in the classroom. Thus,

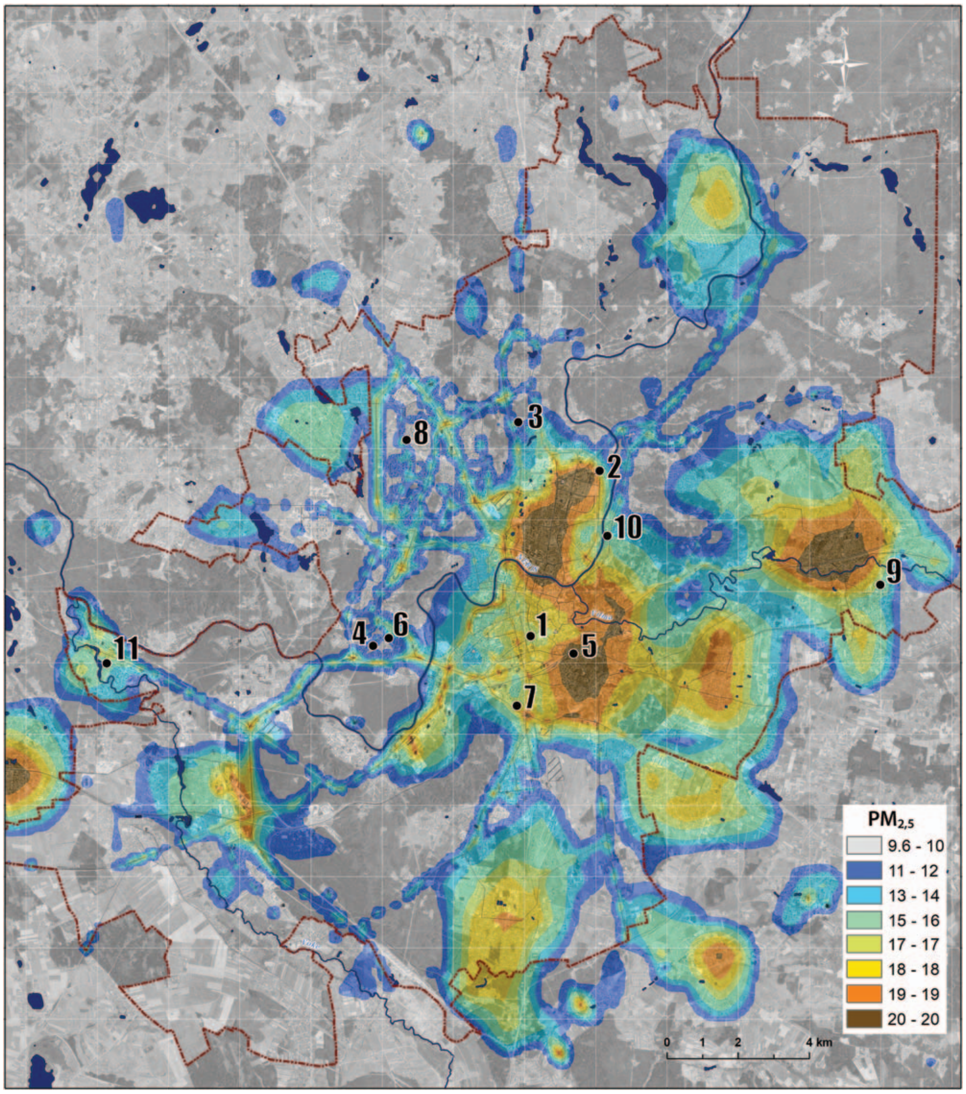

Figure 1: Location of the schools engaged in the research in Vilnius. The scheme of average annual fine particle mass concentrations of sizes up to 2.5 μm ($PM_{2.5}$) in 2018.[17]

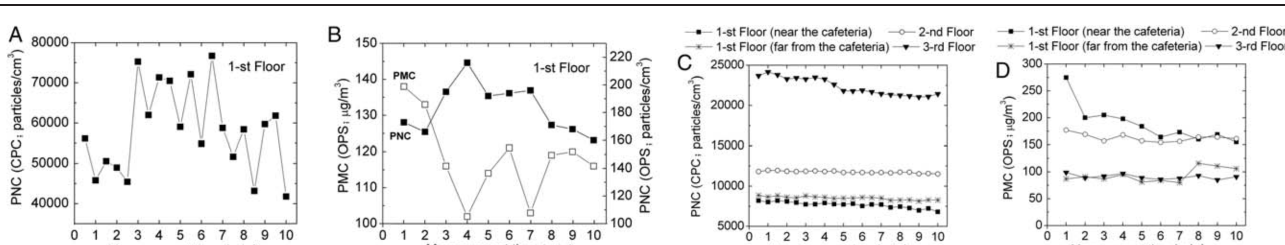

Figure 2: A course of total particle number concentration (PNC [CPC]) (A), particle number concentration (PNC [OPS]) and particle mass concentration (PMC [OPS]) (B) measured near the cafeteria in school No. 3, PNC (CPC) (C) and PMC (OPS) (D) in the classrooms on the first, second, and third floors in autumn. CPC: Condensation particle counter; OPS: Optical particle sizer.

during the lesson when all windows were closed, rather elevated PMC values in the classroom on the first floor were estimated between 90 and 120 $\mu g/m^3$ [Figure 2A–D].

In winter, near the cafeteria, very high PNC (CPC) and PMC (OPS) values were measured and estimated. A peak of PMC (about 500 $\mu g/m^3$) was estimated when the door to the cafeteria was opened and a group of pupils left the cafeteria. PNC (CPC) in the corridor on the third floor decreased with time down to values of outdoor air when the windows were opened. In the second-floor corridor, PNC stayed nearly constant during the lessons (squares) and lesson break interval (circles) when the cafeteria ventilation was switched on. PMC on the third floor showed a peak during a lesson break up to 560 $\mu g/m^3$ [Figure 3A and 3B].

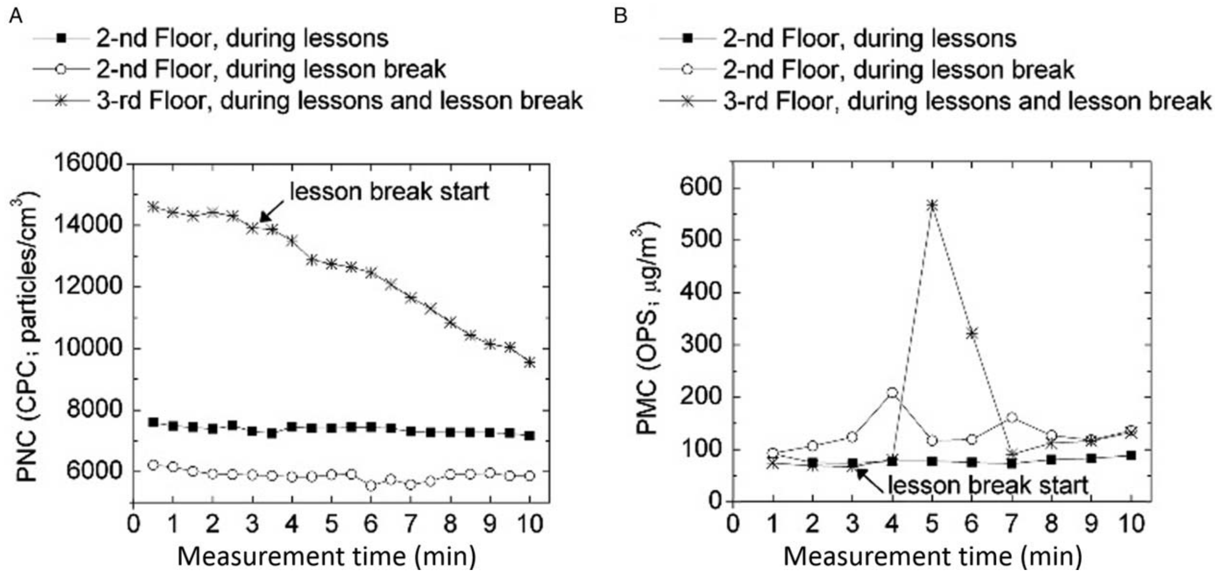

Figure 3: Total particle number concentration (PNC [CPC]) (A) and particle mass concentration (PMC [OPS]) (B) measured in the corridors on the second and third floors in school No. 3 in winter. CPC: Condensation particle counter; OPS: Optical particle sizer.

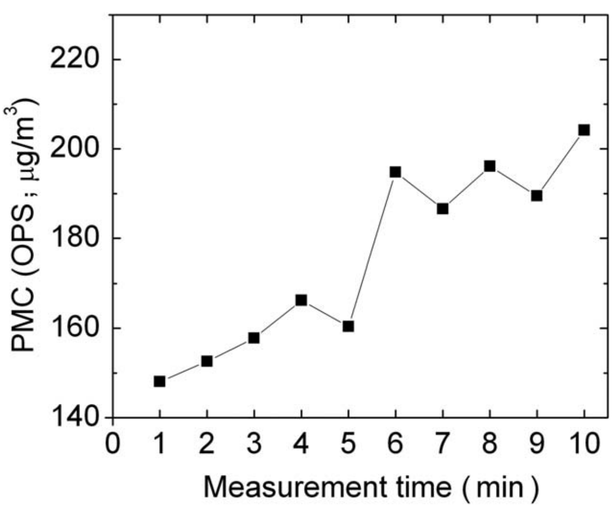

Figure 4: During a lesson break, particle mass concentration (PMC) rise in the corridor with a carpet on the third floor in school No. 6. OPS: Optical particle sizer.

A use of carpets and soft furniture in schools

Classrooms, corridors, and lounges in many schools are furnished with soft furniture (chairs, cushions) and carpets. In primary schools, wardrobe coat racks are often organized in classrooms, as well. Soft articles may be a source of particles. In school No. 6 in a corridor with a large carpet (3 m × 5 m), a significant rise in PMCs occurred with pupil activity at the beginning of the lesson break [Figure 4].

Summary of seasonal data on PNC (CPC) and (OPS) in the schools participating in the research project

Seasonal data on PNC (CPC) and (OPS) in the schools participating in the research are presented in Tables 1 and 2 (autumn), Tables 3 and 4 (winter), and Tables 5 and 6 (spring). It can easily be seen that the highest PNC (CPC) values in classrooms were measured in schools No. 3 and No. 4 due to the respective high PNC values measured in cafeterias [Table 1]. Elevated outdoor PNC (OPS), which exceeded their maximum indoor values in the classrooms, were only measured near school No.1 [Table 2]. Maximum PMC (OPS) estimated by OPS software in all classrooms in the studied schools varied in the range of 70 to 275 $\mu g/m^3$ and exceeded the outdoor values. It means that in autumn, the cafeterias were the main source of fine (sizes up to 2.5 μm, $PM_{2.5}$) and coarse particles in all studied schools.

During winter of 2017 to 2018, the highest PNC (CPC) values in classrooms were determined in schools No. 1, 3, 4, 5, 6. It was not only due to high PNC values measured in their cafeterias. Thus, in schools No. 4 and No. 5, it was likely, due to high outdoor PNC values. In the absence of ventilation, high PNC maximum values were measured in the cafeterias of schools No. 10 and No. 11. In school No. 10, during the measurements in the classrooms, the ventilation was switched on and low PNC values were obtained [Table 3]. In school No. 11, the cafeteria was located far from the classrooms and had insignificant impact on the situation in the other school lodgements. It explains low PNC values measured in the classrooms [Table 3].

In the winter of 2017 to 2018, outdoor data on PNC (OPS) exceeded the maximum values in classrooms in schools No. 1, 2, 4, 6, 7 [Table 4] and possibly, partially influenced the indoor situation. The respective outdoor data on PMC estimated by OPS software were low and varied in the range of 7 to 25 $\mu g/m^3$. Due to the cafeterias, elevated maximum PMC values were estimated in classrooms in schools No. 1, 2, 3, 8, 10, and No. 11 in the range of 74 to 1348 $\mu g/m^3$. In the classroom in school No. 5, maximum PMC value (about 564 $\mu g/m^3$) was related to the influence of construction works carried out on the unpopulated third floor. Also, the pupil activity during the lesson breaks in

Table 1: Autumn 2017 data on total particle number concentration (PNC [CPC]) (particles/cm^3) in the schools participating in the research.

	Classroom					Cafeteria					
School	Median	Max	Min	95th	5th	Median	Max	Min	95th	5th	Outdoor Extreme value
1	6036	14,507	4642	12,972	4981	47,019	52,705	39,274	50,604	39,274	16,833
2	5152	11,225	4149	9965	4351	11,177	14,273	9723	13,477	9823	13,577
3	10,194	24,158	6808	23,414	7286	58,578	76,739	41,759	75,278	41,759	9595
4	11,878	17,697	9160	16,963	9431	20,892	71,929	14,994	70,674	15,609	7911
5	6408	9052	3592	8890	3720	35,951	39,372	19,808	39,350	19,808	5463
6	5254	8182	3896	7454	4017	35,987	37,157	34,653	37,157	34,653	5371
7	2389	2832	2034	2752	2051	19,128	22,272	17,516	22,272	17,516	4939
8	6641	7718	4417	7525	4640	34,200	40,696	32,307	40,485	32,307	4304
9	2262	5131	1784	5087	1821	4400	5088	4175	4937	4175	4454
10	2879	3310	1895	3240	2027	4563	5393	3518	5393	3518	3595
11	1965	4042	1742	2319	1831	6439	8361	5901	8361	5901	2664

CPC: Condensation particle counter.

Table 2: Autumn 2017 data on particle number concentration (PNC [OPS]) (particles/cm^3) in the schools participating in the research.

	Classroom					Cafeteria					
School	Median	Max	Min	95th	5th	Median	Max	Min	95th	5th	Outdoor Extreme value
1	151	248	119	230	122	492	833	451	833	451	287
2	32	101	19	50	20	52	311	46	146	46	74
3	72	110	68	83	68	182	216	160	216	160	89
4	26	48	23	47	23	37	252	33	252	33	36
5	97	284	64	152	66	288	366	197	366	197	100
6	41	118	25	83	26	161	180	157	180	157	32
7	94	123	87	114	87	142	149	136	149	136	104
8	20	669	12	230	12	35	37	33	37	33	9
9	19	163	11	28	12	27	43	25	43	25	15
10	57	648	34	381	34	105	123	96	123	96	89
11	36	350	29	114	30	104	233	92	233	92	85

OPS: Optical particle sizer.

Table 3: Data on total particle number concentration (PNC [CPC]) (particles/cm^3) in the schools participating in the research in the winter of 2017–2018.

	Classroom					Cafeteria					
School	Median	Max	Min	95th	5th	Median	Max	Min	95th	5th	Outdoor Extreme value
1	7487	9830	4825	9167	5212	47,934	53,000	38,900	50,701	38,900	13,679
2	3554	6417	1657	6061	1683	12,371	19,324	7481	17,856	7481	10,047
3	6231	10,108	4718	9566	4939	67,751	84,584	42,475	84,584	42,475	7137
4	7288	9561	3942	9287	4006	13,880	17,816	12,192	17,111	12,192	16,909
5	8290	12,379	5177	11,788	5272	6868	7262	6374	7238	6374	18,170
6	7606	11,319	5197	11,078	5285	83,895	97,563	71,348	96,038	71,348	7431
7	5090	7758	4479	7556	4839	9757	28,113	8840	28,113	8840	9949
8	4427	4973	3206	4669	3273	23,395	43,529	13,013	36,016	13,013	6092
9	4004	6853	1880	6630	1962	12,330	14,730	10,066	14,730	10,066	7871
10	2728	3289	2143	3215	2269	15,725	74,979	8681	64,603	9002	5163
11	2881	3536	2633	3477	2641	47,108	62,527	39,813	54,446	39,813	5091

CPC: Condensation particle counter.

Table 4: Winter (2017–2018) data on particle number concentration (PNC [OPS]) (particles/cm^3) in schools participating in the research.

School	Classroom					Cafeteria					Outdoor Extreme value
	Median	Max	Min	95th	5th	Median	Max	Min	95th	5th	
1	151	176	128	170	131	490	818	443	818	443	203
2	128	148	100	146	101	237	354	175	354	175	238
3	156	329	100	263	101	249	349	184	349	184	196
4	128	142	97	140	98	174	268	169	268	169	201
5	198	315	162	276	163	154	155	149	155	149	212
6	211	272	156	260	158	469	487	442	487	442	283
7	154	221	95	219	95	159	180	147	180	147	285
8	42	57	37	47	37	112	286	70	286	70	44
9	90	190	55	134	56	121	267	119	267	119	160
10	102	216	68	184	68	135	190	118	171	118	120
11	214	289	158	277	158	386	448	364	448	364	282

OPS: Optical particle sizer.

Table 5: Spring 2018 data on total particle number concentration (PNC [CPC]) (particles/cm^3) in the schools participating in the research.

School	Classroom					Cafeteria					Outdoor		
	Median	Max	Min	95th	5th	Median	Max	Min	95th	5th	Median	95th	5th
1	7107	11,808	4527	10,579	4552	15,694	39,790	10,240	36,014	10,506	4563	5448	4293
2	3974	17,205	2957	15,391	3052	4441	54,031	3894	42,236	4051	2765	2858	2648
3	3520	5212	2723	5011	2832	3883	4303	3729	4236	3729	2781	4248	2529
4	9146	16,149	4960	15,901	5047	53,910	95,535	8595	91,190	8595	6114	6528	5740
5	5113	6729	4363	6613	4377	19,880	33,808	15,461	30,615	15,461	4114	4695	3725
6	6549	9056	4275	8738	4448	69,185	74,759	46,355	73,338	46,355	3508	4473	3188
7	5708	8335	4024	8107	4535	24,863	33,246	17,016	33,023	17,016	4635	6261	4311
8*	6451	8638	3627	7091	3684	13,890	20,849	10,162	18405	10,162	3727	4163	3341
9	2717	3187	2158	2866	2177	3802	4108	3513	3970	3513	2289	2610	2169
10	3609	30,999	1734	25,983	1895	5587	84,026	1780	68,121	1847	1833	3929	1584
11	2064	30,995	1105	29,232	1126	31,770	44,846	27,612	42,329	27,612	1953	2165	1897

* In this case, data were estimated without an influence of an occasional pollution source related to the use of a petrol-powered engine in the schoolyard. CPC: Condensation particle counter.

lodgements with the soft furniture induced elevated PMC values.

In spring of 2018, rather low outdoor PNC (CPC) values were measured in all studied schools [Table 5]. In schools without adequate ventilation, maximum PNC values in their cafeterias in the range of 20849 to 95535 particles/cm^3 were determined. However, elevated PNC median values (7107–9146 particles/cm^3) were calculated only in the classrooms in schools No. 1 and No. 4. Compulsory ventilation systems were switched on in schools No. 2, 3, and No. 9 (low PNC values in the cafeterias). In school No. 2, ventilation was switched on and off during our measurements in the classrooms, which resulted in a rather high range of PNC (CPC) variations (2957–17205 particles/cm^3).

In spring, data on the outdoor PNC (OPS) values showed that they were significantly elevated in schools No. 1 and No. 10 and possibly, influenced the maximum respective values in their classrooms. School No. 1 is located in the downtown and possibly, the intensive traffic emissions were responsible for maximum PNC (OPS) value in the classroom (about 1338 particles/cm^3). In school No. 10, high maximum PNC value (about 502 particles/cm^3) in the classroom was related to the outdoor source – a basketball game. In the other schools, cafeterias and the pupil activity during the lesson breaks were responsible for the elevated PNC values in the classrooms [Table 6].

In spring of 2018, estimated PMC (OPS) maximum values in the classrooms in studied schools varied in the range of 99 to 1037 μg/m^3. The latter high value was caused by construction works, which were performed on the second floor in school No. 3. A significant indoor PMC value (about 227 μg/m^3) was also estimated in the classroom in school No. 10 during a basketball game on the sport yard (outdoor median PMC value was about 272 μg/m^3). In the absence of ventilation, cafeterias influenced elevated PMC values in the classrooms in schools No. 2 and No. 5. Resuspension of deposited particles due to the interior activity of pupils during lesson breaks was responsible for the maximum PMC values in schools No. 1 and No. 6 (236–261 μg/m^3) when the ventilation systems in the cafeterias were switched on. In schools No. 7 and No. 8, outdoor pollution may be responsible for rather high maximum

Table 6: Spring 2018 data on particle number concentration (PNC [OPS]) (particles/cm^3) in the schools participating in the research.

	Classroom					Cafeteria					Outdoor		
School No.	Median	Max	Min	95th	5th	Median	Max	Min	95th	5th	Median	95th	5th
1	183	1338	86	944	86	132	149	121	147	121	1094	1188	675
2	34	84	31	42	31	39	459	33	62	33	35	39	31
3	61	235	38	106	38	53	134	51	134	51	42	75	34
4	16	27	13	25	13	89	264	59	264	59	13	15	12
5	64	136	47	79	48	89	137	58	134	58	39	43	38
6	20	180	14	90	14	28	77	25	77	25	24	28	20
7	48	90	44	86	45	49	50	47	50	47	52	58	45
8	33	52	21	45	21	39	49	33	49	33	25	33	23
9	66	144	59	94	61	64	75	63	75	63	59	65	58
10	32	502	10	330	10	16	33	13	31	13	593	1088	43
11	17	124	11	46	11	92	111	89	111	89	17	18	17

OPS: Optical particle sizer.

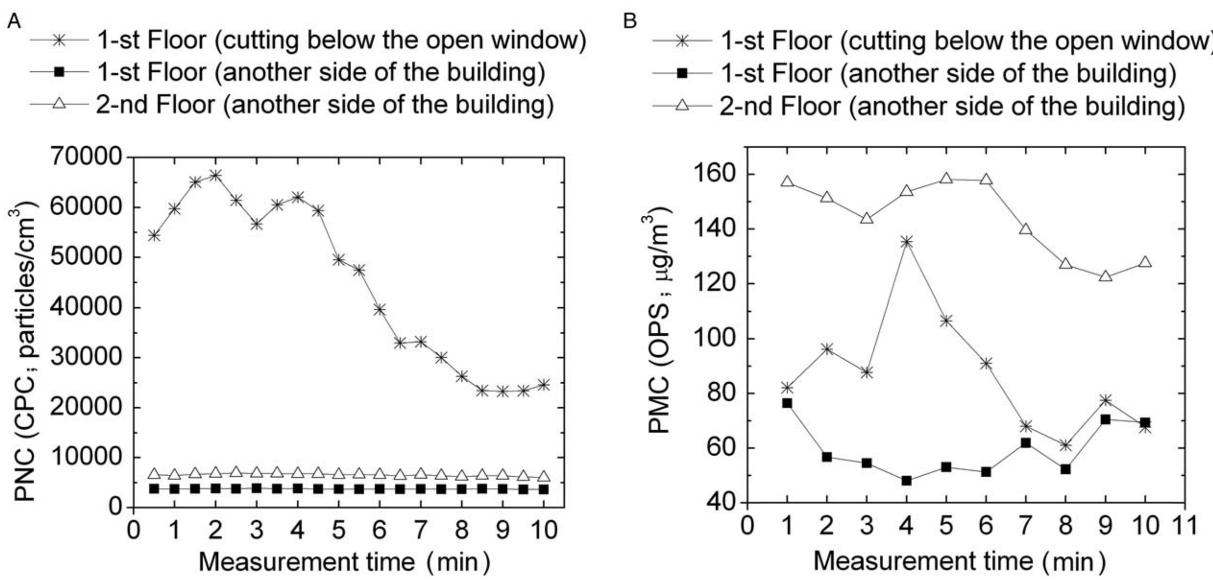

Figure 5: Total particle number concentration (PNC [CPC]) (A) and particle mass concentration (PMC [OPS]) (B) in the classrooms of school No. 8 before (squares; triangles) and during the power tool use near the school (asterisks). CPC: Condensation particle counter; OPS: Optical particle sizer.

PMC values (152 and 158 μg/m^3, respectively) in the classrooms. Thus, 95th of the outdoor PMC values were equal to 243 and 251 μg/m^3, respectively.

Occasional pollution sources

In addition to the already mentioned sources of indoor aerosol pollution (cafeterias, lesson break activity, soft furniture, and carpets), other occasional pollution sources may be present.

A use of a petrol-powered engine in schoolyard works

In spring, the use of petrol-powered brush cutters or trimmers in the schoolyard during lessons induced a significant increase in fine particle number and coarse PMCs in some classrooms. In school No. 8, a maximum PNC (CPC) value (66,439 particles/cm^3) and PMC of 140 μg/m^3 measured in the classroom on the first floor, were associated with the use of a petrol grass trimmer in the schoolyard.

First and second floor classrooms on the other side of the building had low PNC values. Elevated PMC values of about 158 to 122 μg/m^3 in the classroom on the second floor appear to be related to activity related to the lesson break [Figure 5A and 5B].

Construction works during lessons

In spring, PMC increased in some classrooms on the first floor because of construction work on the second floor for almost a week. The PMC in the classroom, where construction waste was dumped under the windows, reached about 1000 μg/m^3. Other classrooms had PNC (CPC) similar to the outdoor air (3000–5000 particles/

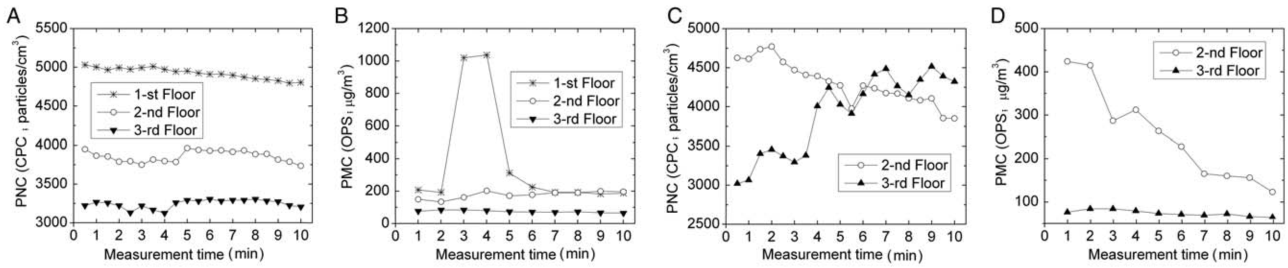

Figure 6: In spring, total particle number concentration (PNC [CPC]) and particle mass concentration (PMC [OPS]) measured and estimated in school No. 3. Measurement locations: in the classrooms (A, B) and in the corridors (C, D). CPC: Condensation particle counter; OPS: Optical Particle sizer.

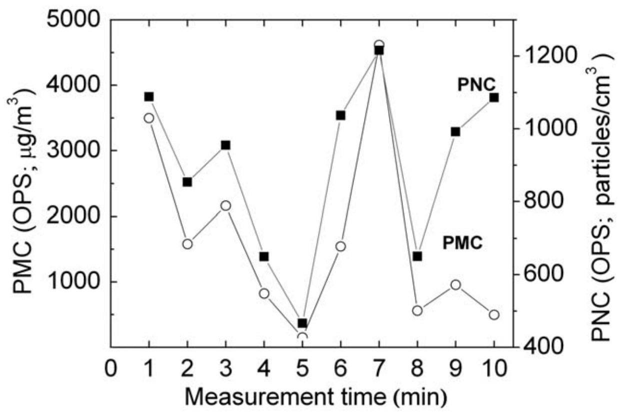

Figure 7: A course of outdoor particle number (squares) and mass concentrations (circles) near the entrance of school No. 10 during a basketball game on the schoolyard. PNC: Particle number concentration; PMC: Particulate mass concentration; OPS: Optical particle sizer.

cm^3). PNC in the corridors on the second and the third floors were similar to those in the classrooms. PMC values in the classroom on the second floor, where the construction work was taking place, were elevated (up to 200 $\mu g/m^3$). Coarse particles due to construction works affected also the situation in the corridor on the second floor where at the beginning of the measurements during the lesson break, PMC (OPS) amounted to about 420 $\mu g/m^3$. On the third minute, lessons began and PMC decreased with time down to about 130 $\mu g/m^3$ [Figure 6A–D].

A use of sandblasting mechanisms for wall scraping near schools

The use of sandblasting mechanisms for wall scraping near schools poses a serious hazard to pupils. The outdoor PNC and PMC values near the entrance of school No. 10 during a basketball game in the schoolyard are presented in Figure 7. Scraping the walls of a neighboring building with a sandblasting mechanism caused the surface of the schoolyard to be covered with a thin layer of scraped particles. An analysis of indoor pollution showed that there were particles in the size range of 0.3 to 3.5 μm diameter.[18] During a basketball game, the particles were lifted off the ground by the children playing and due to wind gusts transferred indoors. To confirm this hypothesis, outdoor measurements were repeated near the schoolyard several times within a month.

Discussion

Pupils of the primary schools spend much time in school premises. Therefore, it is very urgent to determine the air pollution levels and identify its sources indoors for the aim to have more opportunities to control and minimize the pupil exposure. This study found that the main source of aerosol pollution in these schools was related to cafeterias. It is the matter of fact that in the schools, hot meal is always freshly prepared in the local cafeterias. Given the spoilt or inadequate ventilation, school cafeterias turn into a source of high fine and coarse PNC and PMC in the classrooms. Daisey *et al*[19] designated that inadequate ventilation and high CO_2 concentrations in the US schools are related to the elevated health risks for pupils. The importance of cafeterias as a source of indoor ultrafine particle (less than 0.1 μm in diameter) concentrations in classrooms has been found in the other studies.[20,21] Cooking and eating time was responsible for 83% of the total ultrafine particle exposure in schools in Italy.[22] The effects of petrol-powered tools should be expected with the well-known association of traffic related particle matter generation. Thus, it was determined in the study of Rivas *et al*[23] that elevated mineral contents of indoor $PM_{2.5}$ measured in Barcelona schools were due to the additional component of microelements of traffic emissions previously deposited on the sand-filled school sport yards. Being scraped from the sand particles and lifted off the ground during games, those microelements were easily transferring indoors.

Soft furniture, carpets, wardrobes in the classrooms, dusty wear and cleaning without wetting surfaces appear to be the cause of increased coarse particle concentrations probably by re-suspension from the surfaces. The PNC and PMC increase from the beginning of the lesson break could relate not only with the soft furniture and carpets, but also with the pupil clothes. Textile fragmentation due to friction may be also a source of coarse aerosol particles. The influence of pupil clothes fibers on the formation of PMCs was observed in schools in Barcelona.[23] Repeated wet cleaning of school premises may help reduce the recirculation of particle matter in schools.

This study also showed that construction work during school hours and sandblasting mechanisms in the neighborhood of schools are important hazards. It is known[24] that construction works are always followed by emissions of airborne substances, which induce harmful effects on health. Thus, volatile organic compounds released in the gas form from building materials can negatively affect central nervous system. Particulate matter as fragments of mineral wool and fiberglass can irritate respiratory system, eyes and skin. Disturbing dirty areas during construction works, particulate matter may consist from debris of paint materials toxic to nervous system, heavy metals and carcinogenic asbestos. Particulate matter may also consist of biological materials, such as mold and fungi, which can induce infection and allergic diseases.

Conclusions

The results of our survey show that even in relatively low polluted region of Eastern Europe there are big differences in aerosol pollution within a city. Only in two suburban Vilnius schools could the situation be considered satisfactory with respect to indoor particle matter concentrations. In the other schools, in different seasons, maximum values of the aerosol number and mass concentrations in classrooms varied in the range of 2800 to 31,000 particles/cm^3 and of 70 to 590 $\mu g/m^3$, respectively. Aerosol mass concentrations in classrooms associated with construction works reached almost 1000 $\mu g/m^3$. Outdoor aerosol mass concentrations during casual events such as the use of sandblasting mechanisms near the schools may reach several mg/m^3. Therefore, carrying out of such works should be restricted.

During all seasons, cafeterias were the main source of indoor air pollution in these schools due to the spoiled or inadequate ventilation. In winter, pupils spend most time indoors and soft furniture, carpets, and pupil clothes could be an additional source of elevated PMC in classrooms and corridors. Therefore, frequent wet cleaning of the premises and monitor of the ventilation systems will help improving air quality in school lodgements. Considering that indoor aerosol sources are mainly responsible for the pollution levels in school premises, the proposed method for assessing aerosol air pollution in schools, conducted in the frame of a pilot study, can be further used to collect statistics on air pollution and establish correlation with data on respiratory diseases of pupils.

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Conflicts of interest

None.

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