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DETERMINATION OF TRACE ELEMENTS IN CLASSROOM AEROSOLS

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COMMUNICATION

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OZNACZANIE PIERWIASTKÓW ŚLADOWYCH W AEROZOLACH SALI LEKCYJNEJ

W pracy przedstawiono wyniki badania zawartości pierwiastków śladowych, składu ziarnowego i mineralnego cząstek aerozolowych i cząstek osiadłego pyłu w jednej z sal ćwiczeniowych Politechniki Lubelskiej. Porównano je z wynikami takich samych badań dla cząstek aerozolowych i osiadłego pyłu na zewnątrz budynku. Porównanie to wykazało znaczące różnice w jakości i zawartości części stałych w powietrzu wewnętrznym i zewnętrznym. Cząstki aerozolowe wewnątrz pomieszczenia zawierały więcej Ca i K, natomiast na zewnątrz budynku zawierały więcej Fe i Pb. Na podstawie uzyskanych danych podjęto próbę identyfikacji źródeł aerozolowych skażeń powietrza wewnątrz sali. Zwrócono uwagę na znaczenie badań cząstek aerozolowych przy ocenie ekspozycji studentów (uczniów) na określone, specyficzne skażenia znajdujące się we wdychanym przez nich powietrzu. Wskazano również na użyteczność takich badań dla działań mających na celu eliminację źródeł niebezpiecznych, aerozolowych skażeń w szkołach.

Summary

The nature and concentration of aerosol particles affect the classroom indoor air quality and have a significant impact on children's and youth's health. The results of investigation of trace elements concentrations, grain size and mineral distribution of aerosol particles and precipitation inside one of the classrooms in Lublin University of Technology have been presented. They were compared with the results of investigation of outdoor aerosols and precipitation. A significant difference between the indoor and outdoor particulate matter was shown. The indoor aerosols contained more Ca and K, while Fe and Pb predominated in outdoor aerosols. The attempt to identify sources of pollution in the classroom indoor air was undertaken on the basis of these results. It was emphasized that quantitative data from studies of aerosol particles in classrooms could play an important role in determination of students' exposure to specific contaminants connected with inhaled aerosols. Utility of such investigations for activities which eliminate sources of hazardous aerosols in schools was also pointed out.

INTRODUCTION

Nowadays people spend most of their time indoors, so considerable attention is directed towards the problem of indoor air quality. It has become clearer that serious health problems are linked with indoor air pollution. Comparative risk studies have constantly ranked indoor air pollution among the top environmental risks to the public health [8]. Students are at greater risk because of the time spent in school facilities and because children and youths are more susceptible than adults to the harmful effects of indoor air pollutants [19].

Recent studies have indicated significant students' health risk associated with exposure to fine particles. According to the U.S. studies [7, 11] poor indoor air containing a variety of particles is reported in about 20% of all schools. Suspended fine particles in classroom air are significantly responsible for increased allergies, respiratory infections and asthma exacerbations, which in turn are related to reduced attendance and performance of students. These health problems have reached almost epidemic proportions, e.g. nearly five million children, or 11% of the U.S. child population, have asthma – a leading cause of school absenteeism and pediatric hospital admission [7].

Studies in Europe also lead to alarming conclusions [2, 18]. Poor indoor air quality is common in schools in many European countries. Allergic problems among children are mainly caused by indoor aerosols and particles of dust and dirt brought indoors from outside air. Thus, the direct associations between students' health problems and classroom aerosols seem to be evident. Therefore an interest in classroom aerosols and their relation to outdoor aerosols increased and their measurements are crucial in future indoor air quality research in schools.

This paper presents some preliminary results of the investigation of trace element concentrations, grain size and mineral distributions of aerosol particles and precipitation inside and outside the classroom.

MATERIALS AND METHODS

The subject of investigation was suspended particulate matter (SPM) in indoor air of one of the lab-classrooms of Lublin University of Technology (LUT). The classroom was located on the 2nd floor of the 5-store laboratory building and had natural ventilation. During the investigation no classes were conducted in this room. The SPM was sampled on the breathing level (1.5 m). Simultaneously the SPM in the outdoor air was sampled outside the windows of the classroom. The windows over looked the inner road between the LUT buildings, where students' and LUT workers' cars were parked. The sampling was performed during the heating season, in February with alternately snowy and rainy weather. The sampling of the total suspended particulates in indoor and outdoor air was performed according to the procedures described in the document IAEA-TECDOC-950 [17].

The separate samples were collected after 20 hours, 1 day and 3 days of indoor and outdoor air filtration respectively. The applied sampling device consisted essentially of a small volume flow rate pump and a filter. The operational flow rate was 2 dm^3/min. The following types of filters were used: mixed cellulose ester (MCE) of a 25 mm diameter and pore size 0.45 μm (filter F1), MCE of a 25 mm diameter and pore size 0.8 μm (filter F2) and MCE of a 37 mm diameter and pore size 0.45 μm (filter F3). Three different sampling times and two different filter diameters and pore sizes were used in testing their influence on the accuracy of the trace analysis. The energy dispersive X-ray fluorescence (EDXRF) method with Mo secondary target excitation geometry was applied. The spectrometric measurements were performed following the detailed guidance of Handbook for X-ray Spectrometry [21]. The tube voltage was set to constant value 45 kV. The current was chosen individually for each analyzed sample to derive the optimum excitation conditions, namely best precision and detection limits. To minimize the risk of contamination, samples were analyzed directly without any preparation, with the filters' loaded side towards the excitation X-ray beam. The measurements were performed according to the U.S. EPA Method 626/R-96/010a [3]. The filters' blank values were determined and complied in the results of the analysis. It was assumed that for the filters used the sampled aerosols were collected mainly on the filters' surface, so the particle size effect was kept low. It was also assumed that the particles were uniformly deposited over the collection area of the filters. Particle size distributions were estimated by a laser counter. Details regarding this estimation are presented elsewhere [15].

Additionally to the aerosol analysis, determinations of trace elements and minerals in precipitation outside and inside the investigated classroom were performed. The dust was collected on a flat glass surface generally following the U.S. OSHA Guidelines for Surface Sampling [10]. The determination of trace elements in the settled dust was performed using the total reflection X-ray fluorescence (TXRF) method described in the document IAEA-TECDOC-950 [17]. Determination of minerals in the settled dust was performed using the wavelength dispersive X-ray fluorescence (WDXRF) method following the guidance of study techniques of minerals [1].

RESULTS AND DISCUSSION

The exemplary results of XRF measurements for aerosols collected on different filters in different time are presented in Table 1. The detection limits of some of the determined trace elements for two different filters at standardized 8 hours of air sampling at the flow rate of 1 dm^3/min. and for XRF measurement time 1000 s and current 40 mA are also presented. Only those results which were obtained for the same kind of filters are directly comparable. Concentrations of almost all elements (expressed in ng/m^3) obtained for sampling time 20 h and for sampling time 1 day are below the method's detection limit. It can also be seen that after standardization of sampling and measurement conditions, the results for aerosol samples collected for at least 3 days could be a subject of examination. The comparison of trace elements concentrations in indoor and outdoor aerosols is shown in Figure 1.

On the basis of these preliminary results it can be observed that the investigated indoor aerosols contain more calcium and potassium than the outdoor aerosols. The chalk made out of natural calcium minerals, which is used for writing on the blackboard, could be responsible for that relation. The concentration of lead is also slightly higher in indoor aerosols. It could be connected with the lead based paint which once was used for painting the classroom walls and window frames. On the other hand, the concentration of iron is slightly higher in outdoor aerosols. It could be caused primarily by fly ashes which are present in outdoor air. The reason for their presence may be the existence of the city's two conventional power plants. The other reason could be exhausts from the cars, both parked and moving near the sampling site.

Considering the impact of outdoor generated air pollution on indoor air quality the specific "street canyon" effect needs to be taken into account [12]. In the considered case, vehicle movement and induced air turbulence may result in an elevation of pollutant

Table 1. Trace elements in indoor and outdoor aerosols

Element	Sample							DL [ng/cm^2]	
	IN 3d - F1	OUT 3d - F1	IN 1d - F1	OUT 1d - F2	IN 1d - F2	OUT 20h - F3	IN 20h - F3		
	Concentration [ng/cm^2]								
K	983 ± 79	681 ± 75	293 ± 62	198 ± 48	275 ± 57	296 ± 42	210 ± 61	305 ± 6	
Ca	280 ± 88	< 95	–	< 67	141 ± 72	< 67	–	212 ± 3	
Fe	283 ± 13	357 ± 20	89 ± 16	–	–	305 ± 19	38 ± 16	45 ± 1	
Cu	–	–	–	16 ± 8	< 17	–	< 17	39 ± 1	
Zn	214 ± 16	191 ± 16	< 15	49 ± 7	34 ± 7	38 ± 8	32 ± 9	33 ± 1	
Br	25 ± 4	29 ± 3	10 ± 2	< 6	< 9	< 6	< 9	20 ± 1	
Pb	71 ± 7	55 ± 7	< 19	17 ± 4	< 19	< 13	< 19	42 ± 2	
Ni	–	–	< 18	16 ± 4	22 ± 6	15 ± 4	26 ± 7	41 ± 1	
	Concentration [ng/m^3]							DL$_{F1,2}$ [ng/m^3]	DL$_{F3}$ [ng/m^3]
K	825 ± 70	599 ± 66	< 806	< 806	< 806	< 2311	< 2311	2419 ± 48	5777 ± 115
Ca	246 ± 77	< 187	–	< 560	< 560	< 1604	–	1679 ± 26	4009 ± 62
Fe	249 ± 11	314 ± 18	235 ± 42	–	–	966 ± 60	< 343	359 ± 11	858 ± 26
Cu	–	–	–	< 103	< 103	–	< 295	309 ± 11	738 ± 27
Zn	188 ± 14	168 ± 14	< 88	129 ± 18	90 ± 18	< 251	< 251	263 ± 11	627 ± 26
Br	22 ± 4	26 ± 3	< 54	< 54	< 54	< 153	< 153	161 ± 7	384 ± 17
Pb	62 ± 6	48 ± 6	< 111	< 111	< 111	< 318	< 318	333 ± 14	796 ± 32
Ni	–	–	< 109	< 109	< 109	< 312	< 312	327 ± 9	781 ± 22

IN / OUT – samples of indoor / outdoor aerosols

d / h – time (days / hours) of sampling

F1,2 / F3 – MCE 2.5 cm / 3.7 cm diameter filters

DL$_{F1,2}$ / DL$_{F3}$ – detection limits for elements in aerosols collected on F1,2 / F3 filters during standardized 8 h sampling at a flow rate 1 dm^3/min, for XRF measurement time 1000 s and current 40 mA

< – concentration below detection limit for given filter, time of sampling and XRF measurement conditions.

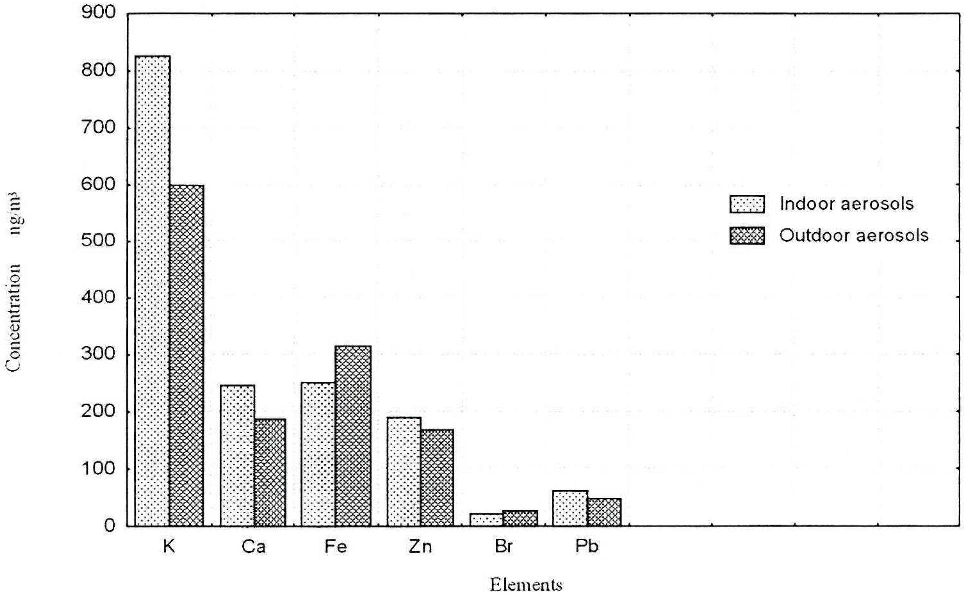

Fig. 1. Trace elements in indoor and outdoor aerosols

concentrations on certain heights. The variable vertical profile of pollutant concentrations certainly plays a significant role in this particular case, because classroom air inlets (windows and ventilation openings) are located on the 2nd floor. Irregular concentration changes of indoor aerosol grain fractions presented in Figure 2 could be a direct evidence for these variations in the pollutant profile. According to the detailed studies [5] concentration of fine and ultra-fine particles decreases to about 50–60% from the approximate ground level readings (between heights of 0 to 6 m), to full building height (from 24 to 33 m above the ground).

Partially concentration changes of indoor aerosol grain fractions are also coerced by indoor microclimate fluctuations [4, 13], which are in turn related to the classroom ventilation efficiency [6].

The results of trace element determination in the precipitation inside the classroom are shown in Table 2. It can be seen that the settled particulate matter contains significant amounts of Ca, K, Fe, Ti and Zn.

In accordance with the results of many studies [9, 14] a kind of outdoor and indoor air pollution, efficiency of classroom ventilation and air filtration systems and also particle-generating activity of students have a major effect on the chemical content of settled dust.

The mineral content of studied indoor and outdoor aerosols is indicated in the roentgenogram in Figure 3. The outdoor aerosols contain more quartz, illite and feldspar while indoor aerosols implicate more gypsum and calcite. These results verify higher concentration of calcium and potassium in classroom aerosols. The determinations of minerals together with analyses of microbes [20] and organic compounds [16] in classroom aerosols conduce to a better understanding of the properties, behavior and health effects of particulate matter of indoor and outdoor origin.

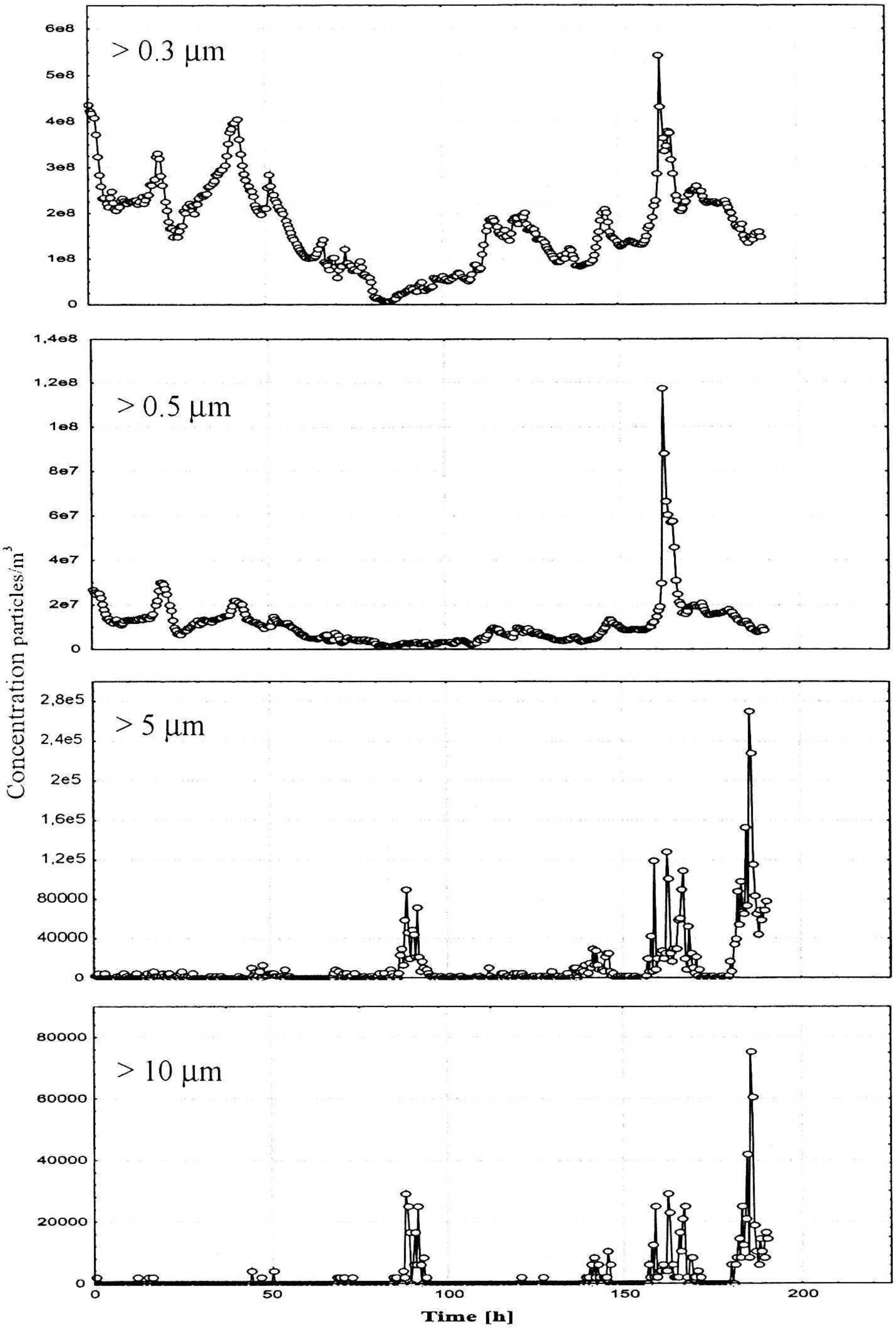

Fig. 2. Changes of grain fractions in the classroom aerosols

Table 2. Trace elements in dust settled inside the classroom

Element	Concentration [ppm]
K	7.419
Ca	30.219
Ti	4.426
Cr	0.095
Mn	0.197
Fe	9.095
Co	0.078
Ni	0.026
Cu	0.032
Zn	2.432
Se	0.237
Rb	0.032
Sr	0.209
Y	0.025
Ba	0.881
Au	0.102
Hg	0.063
Pb	0.102

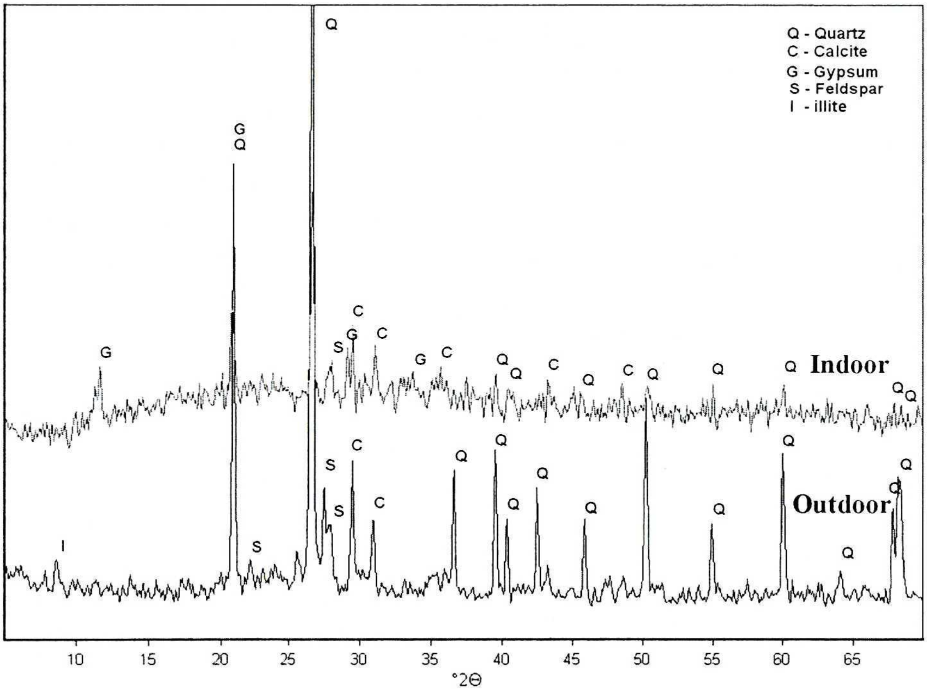

Fig. 3. Mineral content of indoor and outdoor aerosols

CONCLUSION

Determination of trace elements in classroom aerosols and precipitations can play an important role in the evaluation of indoor environment quality in schools. It could provide significant data on the influence of outside and inside air parameter and pollution level changes on students' exposure to specific contaminants. The recognition of ambient air pollution and understanding the health risks associated with particular matter in classroom air could help to eliminate potential sources of hazardous aerosols in schools.

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