School Environment and Respiratory Health of Children (SEARCH)

International research project report within the "Indoor air quality in European schools: Preventing and reducing respiratory diseases program"

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The project is implemented with the generous support of the
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I. INTRODUCTION

The goal of the environment and health process can be summarised briefly as the development and maintenance of an environment capable of sustaining the whole population. This goal is very complex and involves a wide range of tasks.

The goal of the process is to improve the state of the environmental factors that influence our health: the quality of air, soil and drinking water, as well as our transport and consumption related habits.

The Regional Environmental Center for Central and Eastern Europe (REC) in collaboration with the Italian Ministry for Environment, Land and Sea implemented the "Indoor Air Quality in European schools. Preventing and reducing respiratory diseases" (SEARCH) international project with special focus on children's health. The project was implemented in Albania, Bosnia and Herzegovina, Hungary, Italy, Serbia and Slovakia from 2006 till 2010. There are two associated countries in the project Austria and Norway.

The outcome of the project is presented in Italy at the 5th Environment and Health Ministerial Conference in 2010.

More then five years has passed since the 4th Environment and Health Ministerial Conference was held in Budapest. As a result of the important work done at the conference, and its outputs, the member states of WHO in the European region have focused their efforts on implementing the conference recommendations, as contained in the Budapest Conference Declaration and the Children's Environment and Health Action Plan for Europe.

The commitments made at the 4th Environment and Health Ministerial Conference include four Regional Priority Goals (RPGs) on:

- water and sanitation
- injuries and accidents
- air quality and
- chemicals, noise, other physical agents and occupational health.

The SEARCH project is a regional cooperation in order to implement the Children's Health and Environment Action Plan, Priority Goal 3: Prevention and reduction of respiratory diseases of children due to out-door and indoor air pollution, by complex research in schools.

There are many environmental health issues in the WHO European region. Stakeholders, working with and between ministries and involving intergovernmental, international organizations and civil society organizations, are making decisions that contribute to sustainable development. The SEARCH project is a *regional partnership* between the REC, the ministries involved in environment and health, the environment and health research institutes, environmental and health authorities, schools and the European environment and health experts.

The donors of the SEARCH project

The main donor of the SEARCH project is the Italian Ministry for the Environment, Land and Sea (IMELS). The ministry supported the SEARCH project to extend the Italian-Hungarian initiatives on indoor air quality in schools to other European countries.

The Hungarian Ministry of Health provided additional support for the researchers of the National Institute of Environmental Health.

Supporter of the associated part of the project

There are two associated countries in the project, Austria and Norway. The research partners from these countries had consultation on the project design, the environmental and health data analysis, the conclusions and recommendations.

The Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management, the Norwegian Ministry for the Environment and the NILU are the supporters of the associated countries.

II. THE DESCRIPTION OF THE SEARCH PROJECT

2.1 The background

The SEARCH project is built on a pilot project, “Cleaner Environment, Better Future for Our Children”, which was coordinated by the Regional Environmental Center for Central and Eastern Europe, Country Office Hungary in 2004. The pilot project was based on the Italian–Hungarian bilateral cooperation and its aim was to improve indoor air quality in schools, to reduce the number of children suffering from respiratory diseases, and to lower the risk of further cases.

The long-term goal of the pilot project was to develop suggestions for preventive and legal measures and criteria for controlling indoor air quality with special attention to various allergies in further work.

Researching the health of schoolchildren, the experts of the National Environmental Health Institute of Hungary found that the outdoor and indoor environment of schools, the standard of living of families and the parental attitudes to childhood health issues determine the incidence of respiratory disease among students.

The capacity building of the school staff was an important component of the pilot project.It included the development of a training programme on indoor air pollution designed for all workers and employees in educational institutions. There are two main parts of the training programme. The first is “The possible dangers of air in closed rooms” and the second is “The benefits of environmentally friendly cleaning”, which mainly consists of practical suggestions (how to clean the classrooms).

The first chapter of the training material lists the harmful substances found in schools and emphasizes the importance of ventilation, of the absorption of dangerous substances in air by indoor plants, and of the proper renovation of classrooms. The second chapter on cleaning deals with the health impacts of cleaning agents used in schools and offers alternatives in order to promote environmentally and health-friendly cleaning.

Five pilot schools used the training programme during the first half of 2004. Since autumn 2004 they have been successfully employing the methods described, integrating them into their environment and health educational programmes of the schools. (É. Csobod, J. Heszlényi and Á. Schróth: *Improving Indoor Air Quality in Schools,* 2004, REC, Hungary, www. rec.org/SEARCH)

Due to the successful outcome of the pilot project above, the Italian Ministry for the Environment, Land and Sea supported the implementation of the SEARCH project in six countries.

2.2. The focus of the SEARCH project

The SEARCH project focuses on two main points:

1.Implementation of the European Environment and Health Policy and Action Plan by active involvement in the European processes and by the development of efficient instruments and tools for multi-stakeholder cooperation.

2. Regional participation in the implementation of the Children's Health and Environment Action Plan, Priority Goal 3: Prevention and reduction of respiratory diseases of children due to out-door and indoor air pollution, by complex research in schools.

The objectives of the project

The major objectives of the SEARCH project are the followings:

1. to assess the relationship between the school environment and the children's health

2. to make recommendations for improving the quality of school environment at the 5th European Environment and Health Ministerial Conference in Italy, in 2010.

3. to transfer awareness raising initiatives for the prevention of respiratory diseases, particularly among children, that have already been successful in Italy and Hungary.

2.3. The research design of the SEARCH project

There are three parts of the study:

1. Exposure assessment in schools:

   a.) measurement of the indoor air quality in the school

   b.) assessment of the school building and maintenance

   c.) assessment of the home environment

2. Assessment of the children's health status

    a.) symptom questionnaire
    b.) measurements of lung function

3. Finding association between school environment and children' s health based on the analysed data of the project

2.4. Implementation the SEARCH project (2006-2010)

There are two parts of the project implementation. The first is Environmental and health assessment (I), the second is Capacity Building and awareness raising (II), which builds on the identified needs of the schools.

Activities in 2006

I. Exposure assessment

Preparation

1. Adaptation of the Italian-Hungarian concept for the prevention and reduction of respiratory diseases of children in schools. Planning and adaptation of the research design.

2. Selection of the 60 schools (10 schools/country). The selection criteria were developed by the international expert team and were based the goal of the project. (www.rec.org/SEARCH)

3. Preparation of the exposure assessment in the schools. Preparation of the use of the questionnaires in the selected schools to collect data about the environmental quality of the schools (including the air quality). Preparation of the symptom questionnaire to collect information about the health condition of children (1000 children/country).

II. Capacity Building and awareness raising

1. Development and implementation of the publication "Indoor Air quality training program for teachers, parents and school staff" and adaptation of the Italian-Hungarian training initiatives.

2. Consultation with the international expert team about the content and the methodology of the training.

3. Writing the draft of the national version of the training material with the coordination of the expert teachers, and the authors of the brochure "Improving indoor air quality in schools".

Activities in 2007-2008

I. Exposure assessment

Research, collecting data

1. Measurement of the selected indoor air pollutants in certain areas in the selected schools. (Nov 2007-May 2008). Equipment for the measurement were discussed by the expert team of the countries (www.rec.org/SEARCH). REC coordinated the delivery of the equipment for the measurement.

2. The use of the health questionnaire in the selected schools to collect data about the health condition of children (1000/country). The final questionnaire was discussed with the country representatives and the expert team of the project before the translation to national languages.

II. Capacity Building and awareness raising

Launching the Indoor Air Quality training for the selected schools in the six countries mostly after the measurement of the selected indoor air pollutants in the schools. Evaluation of the training.

Finalising and publishing the Indoor Air Quality training brochure in English based on the national experiences.

2009

I. Data analysis and evaluation

1. Data analysis to assess the relationship between the school environment and the children's health.

2. Reporting the result of the assessment at national and international events and consultation.

II. Capacity Building and awareness raising

1. Preparation of the reporting about the outcome of the Indoor Air Quality training program for the side event of the 5th Environment and Health Ministerial Conference in Italy.

2. Reports of the schools about the revised School development plans including the environment and health aspects to improve indoor air quality in the schools.

3. Dissemination of the training materials for other schools in the 8 countries to introduce the Indoor Air quality training concept and sharing the experiences of the schools.

2010

1. Evaluating of the contribution of the SEARCH project to the implementation of the CEHAPE Priority Goal 3 implementation in the project countries.

2. Presentation of the project outcome and policy recommendation in the 5th Environment and Health Ministerial Conference, in Italy in 2010.

3. Evaluation of the use of the training materials in the European countries.

III. RESEARCH ACTIVITIES PERFORMED

1. The Regional Environmental Center for Central and Eastern Europe (REC) and the National Institute of Environmental Health (NIEH) designated the following tasks to be performed by the NIEH:

2. Analysing the association between the environmental and health data obtained from the app. 6000 questionnaires on children's health, schools and classess from Albania, Bosnia and Herzegovina, Hungary, Italy, Serbia and Slovakia

3. Comparison of the above data between the above listed countries participating in the SEARCH project.

Department of Air Hygiene within the NIEH was responsible for planning, preparing and coordinating the air quality measurements technicality, collecting the measurement results, doing partly and organizing the analysis of the exposed samples for all participating countries, and evaluating the Hungarian air pollution data.

The field program was carried out in the heating season, between October 2007 and March 2008.

Formaldehyde, VOCs (benzene, toluene, ethyl-benzene and xylenes), carbon-monoxide (CO), nitrogen-dioxide (NO_2), respirable particulate matter (PM_{10}), carbon-dioxide(CO_2) as the most commonly measured compounds and two characteristic indoor air parameters as temperature(T) and relative humidity(RH) were monitored inside each classroom. In Hungary 43 classrooms in 10 schools were incorporated in the program.

A combination of diffusive sampling (HCHO, NO_2 and VOCs) with 4 day exposure time and continuous monitoring (CO, CO_2, PM_{10} and T, RH) for one day during the teaching period was conducted in each classroom.

In parallel, outdoor air pollution was also controlled.

Additional information about location of the classroom, its volume, ventilation and heating system, furnishing, flooring, wall-covering, type and use of windows and others has been collected using two questionnaires (for both the schools and the classrooms) filled out by the measurement team. The aim of filling out the questionnaires was to identify the potential emission sources affecting the indoor air quality.

The Hungarian measurement results were evaluated for correlation between the indoor sources and the physical parameters, the children's activities and the outdoor pollution level.

IV. RESEARCH RESULTS

The measurement results were analysed for correlation between the indoor sources and the physical parameters of the classes, the children's activities and the outdoor pollution level. A summary of these results is presented in *Table 1.* (Hungarian case)

Table 1. Statistically significant associations between classroom characteristics and the measured levels of indoor air pollutants in Hungary

Classroom characteristics	Pollutants
Number of children in the classroom >20	Increased level of toluene
Classroom facing the street	Increased levels of PM_{10} and CO_2
Classroom floor: wood	Increased levels of PM10, benzene, ethylbenzene, toluene, xylenes, total BTEX and formaldehyde
Classroom wall painted with water-resistant paint	Increased levels of benzene, toluene, ethylbenzene, xylenes, total BTEX,
Classroom wall renewal < 1 year	Increased levels of ethylbenzene, xylenes, total BTEX
Classroom cleaning int he morning	Increased levels of xylene and total BTEX and formaldehyde
Cleaning the classroom floor with broom	Increased level of NO_2
Cleaning the classroom floor with mop	Increased level of toluene and total BTEX

Indoor air measurement data were obtained from 242 classes of schools in the 6 participating countries. Health data were provided for 5.242 children. Associations between the indoor air levels measured in the classes and the children's respiratory symptoms and allergies were evaluated by the NIEH using STATA 10.0 software. The associations between classroom characteristics and the measured pollutant levels were analysed by ANOVA (Analysis of Variance), and tested for significance by Kruskal-Wallis and Mann-Whitney tests. Associations between the measured pollutant levels and the health indicators were assessed by logistic regression, adjusted for gender and age of the children.

Classroom characteristics and health indicators significantly associated with the indoor pollutant levels measured in the 6 countries are summarised in *Table 2.*

Table 2. Classroom characteristics and health indicators significantly associated with the measured levels of indoor air pollutants in the 6 countries

Pollutants	Classroom characteristics	Health indicators
CO_2	Classroom level Number of children in the classroom <$2m^2$/person in the classroom <$6m^3$/person in the classroom Openable window <$2m^2$ Less frequent window opening	Bronchitic symptoms (chronic cough at daytime, or >3months, or with phlegm) Woken up by wheeze at night
PM_{10}	Frequent window opening Classroom cleaning in the evening	Chronic morning cough Attention deficit
Formaldehyde	Classroom cleaning in the evening	Bronchitic symptoms (especially cough with phlegm)
Total BTEX	Classroom level Number of children in the classroom Plastic floor in the classroom Carpet in the classroom Class wall renewal <1year New furniture <1 year	Mould allergy Skin rash Sinusitis
Benzene	Classroom level Number of children in the classroom Carpet in the classroom	Woken up by wheeze
Toluene	Classroom level Number of children in the classroom <$2m^2$/person in the classroom <$6m^3$/person in the classroom Plastic floor in the classroom Carpet in the classroom Class wall renewal <1year New furniture <1 year	Mould allergy Sinusitis
Ethylbenzene	Carpet in the classroom Wall painted with water-resistant paint New furniture <1 year	Diagnosed allergy Drug allergy (diagnosed)
Xylenes	Carpet in the classroom Wall painted with water-resistant paint Classroom cleaning in the morning New furniture <1 year	Diagnosed allergy
NO_2		

Carbon dioxide (CO_2) was a good marker of crowdedness in the classrooms, whichever indicator (Number of children in the classroom, <2 m^2/person or <6 m^3/person in the classroom) was used and it reflected the poor ventilation as well. Both poor ventilation and crowdedness may play an important role in the frequency of respiratory diseases. This way, the association between CO_2 and the respiratory diseases may be regarded rather an indirect than a direct one. The volatile organic compounds are known to be able to irritate the mucosa of the respiratory tract and they may cause allergies as well. These results, however, should be considered as preliminary and therefore interpreted with much cautiousness.

The levels of indoor air pollutants measured in the classrooms of the investigated 60 schools in the 6 participating countries are presented in *Table 3.*

Table 3. Summary of results of the indoor air measurements in the schools of the 6 „SEARCH countries

Classroom characteristics	Albania	Bosnia and Herzegovina	Hungary	Italy	Serbia	Slovakia
PM_{10} (µg/m^3)	69	102	56	82	81	80
Formaldehyde (µg/m^3)	5.61	7.13	2.41	33.07	1.73	8.71
Benzene (µg/m^3)	4.06	6.29	2.16	1.95	5.94	4.84
Toluene (µg/m^3)	15.45	27.58	4.56	5.01	21.94	29.47
Ethylbenzene (µg/m^3)	1.24	1.60	1.64	1.82	1.60	1.38
Xylenes (µg/m^3)	5.03	7.65	7.04	7.10	8.00	5.07
NO_2 (µg/m^3)	12	21	16	19	22	14

The prevalence of respiratory symptoms among the participating children by countries are shown in *Table 4* and that of the doctor-diagnosed allergies can be seen in *Table 5.* There is significant heterogeneity in the prevalence of various symptoms and diseases, therefore the country variable must be included in the logistic regression model when analyzing the associations between the various environmental factors and the health status of the children.

All types of the investigated bronchitic symptoms had the highest prevalence in Albania, especially cough with phlegm. This may partly be explained by the fact that the highest crowdedness was also found in the Albanian schools.

In the case of asthmatic symptoms, Hungary had the lowest prevalence, while the other countries did not differ substantially from each other. Asthma ever diagnosed by a doctor was similarly low in Hungary and Slovakia.

On the other hand, in the case of doctor-diagnosed allergies, these two countries (Slovakia especially) showed the highest overall prevalence.

Table 4. Prevalences (%) of respiratory symptoms and diseases among participating children in the 6 "SEARCH countries"

Symptoms / Diseases	Albania (n=1019)	Bosnia-Herzegovina (n=975)	Hungary (n=704)	Italy (n=915)	Serbia (n=735)	Slovakia (n=894)	Altogether (n=5,242)
Morning cough	18.7	10.6	8.4	13.2	10.5	14.8	13.0
Day/night cough	20.8	9.7	6.5	11.8	9.9	11.0	12.1
Cough >3 months	7.7	3.1	3.3	3.5	3.1	2.4	4.0
Cough with phlegm	41.6	11.9	3.6	8.5	9.4	4.8	14.4
ANY BRONCHITIC SYMPTOM	**53.6**	**24.7**	**13.4**	**22.8**	**21.5**	**24.4**	**28.0**
Wheeze in the last 12 months	6.5	9.2	8.2	11.5	9.4	8.2	8.8
Wheeze after exercise, <12 ms	3.5	5.6	5.8	6.0	5.0	3.6	4.9
Dry cough at night, <12 months	14.2	14.7	10.9	13.9	13.9	15.8	14.0
Woken up by wheeze <12 months	7.4	5.3	2.0	3.6	6.0	5.6	5.1
ANY ASTHMATIC SYMPTOM	**22.8**	**23.3**	**16.9**	**23.4**	**22.9**	**23.9**	**22.4**
DOCTOR-diagnosed asthma, ever	11.8	11.2	7.1	12.2	12.8	7.1	10.5
Asthma treatment, last 12 months	5.7	7.2	3.7	7.9	9.3	6.3	6.7

Table 5. Prevalences (%) of doctor-diagnosed allergies among the participating children in the 6 "SEARCH countries"

Allergies	Albania	Bosnia-Herzegovina	Hungary	Italy	Serbia	Slovakia	Altogether
House-dust mites	13.2	9.7	9.5	8.9	10.1	9.7	10.3
Animal fur, feather	4.9	4.9	9.7	4.4	5.6	6.6	5.8
Pollen	5.9	9.6	12.2	8.9	11.8	14.8	10.3
Mould	5.1	3.4	7.2	3.2	4.1	5.2	4.6
Food	5.3	2.6	8.8	4.9	2.6	5.8	4.9
Drug	5.0	4.1	10.8	3.4	4.5	4.6	5.2
ANY ALLERGY	**19.4**	**17.5**	**23.7**	**17.5**	**17.4**	**28.5**	**20.6**

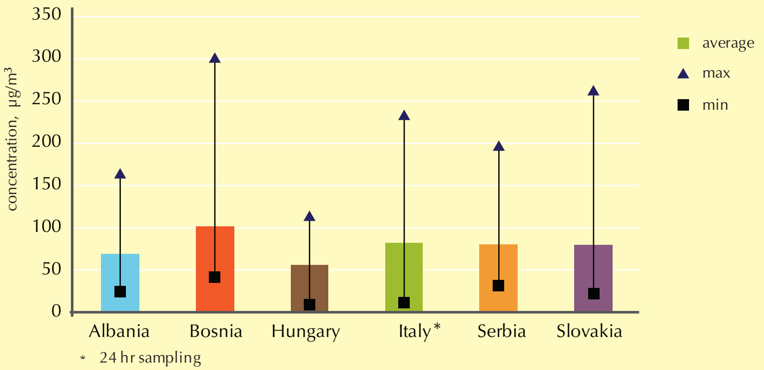
4.1 Environmental measurements

4.1.1 Detailed results of the AIR QUALITY measurements

The indoor concentrations of PM_{10} measured in the classrooms during teaching hours are shown in Figure 1. (In Italy the measurements were performed during 24 hours.) The average concentrations varied between 56-102 μg/m^3, however the maximum values were even 2-3 times higher.

Figure 1

Average one day schooltime indoor PM10 concentrations measured in the classrooms in the SEARCH countries.



The concentrations of benzene measured for 4 days in the classrooms are presented in Figure 2. The average concentrations varied in the range of 2.0-6.3 μg/m^3. In some classes of some countries, however, much higher concentrations were also measured

The concentrations of toluene measured in the classrooms for 4 days are shown in Figure 3. Although the average concentrations varied in the range of 4.6-29.0 μg/m^3, in exceptional cases extremely high values wer also measured.

Figure 2

Four-day indoor BENZENE levels measured in the classrooms in the SEARCH countries.

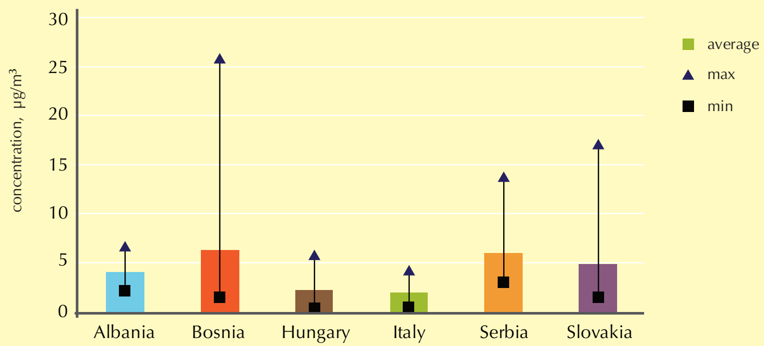
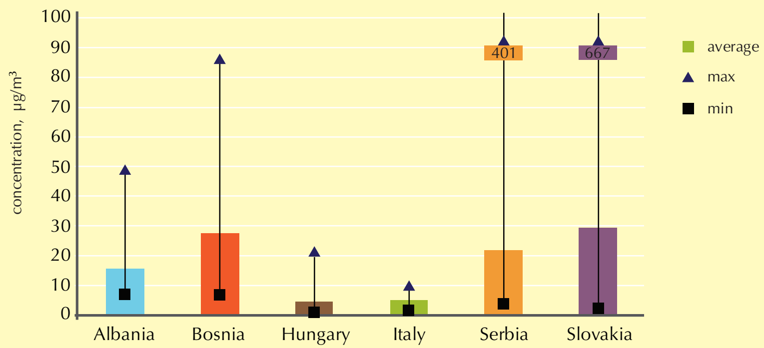


Figure 3

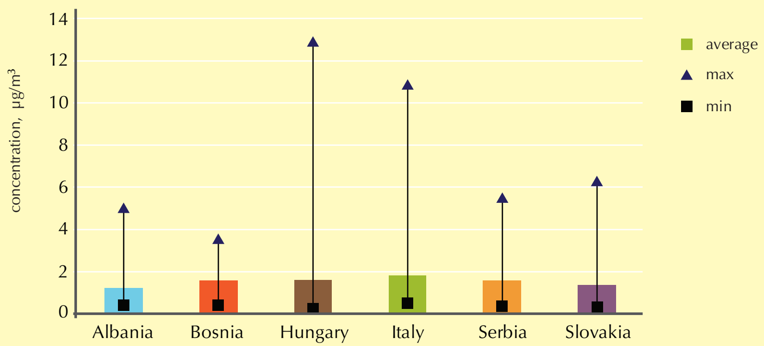
Four-day indoor toluene levels measured in the classrooms in the SEARCH countries.



The concentrations of ethyl-benzene measured for four days in the classrooms are presented in Figure 4. The average concentrations varied in the range of 1.2-2.0 μg/m³, however, maximum values 2-5 times (or even more) higher than that were also recorded.

Figure 4

Four-day indoor ETHYL-BENZENE levels measured in the classrooms in the SEARCH countries.



Concentrations of xylenes measured for four days in the classrooms are presented in Figure 5. The average concentrations varied in the range of 5-8 μg/m³ and the maximum values were between 16 and 70 μg/m³.

The nitrogen dioxide concentrations measured for four days in the classrooms are shown in Figure 6. The average concentrations varied in the range of 12.2-22.1 μg/m³ and even the maximum values were below 50 μg/m³.

The concentrations of formaldehyde measured for four days in the classrooms are presented in Figure 7. The average concentrations varied in the range of 2-33 μg/m³, with high variability among countries.

The indoor/outdoor relationship is illustrated in Figure 8. The results imply that the main source of NO_2 is the ambient air and formaldehyde is primarily emitted by indoor emission sources.

Figure 5

Four day indoor levels of XYLENES measured in the classrooms in all countries.

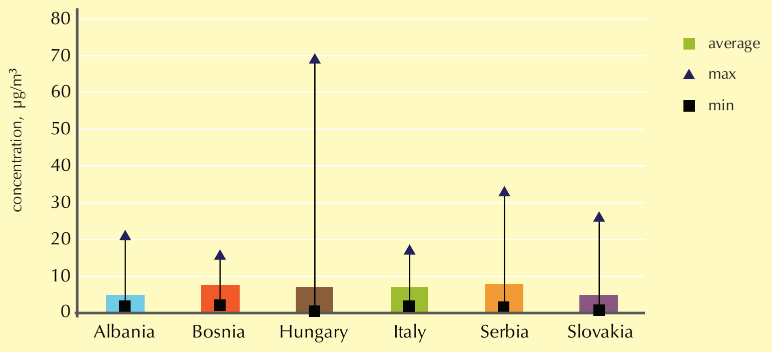


Figure 6

Four-day levels of indoor NITROGEN DIOXIDE measured in the classrooms in the SEARCH countries.

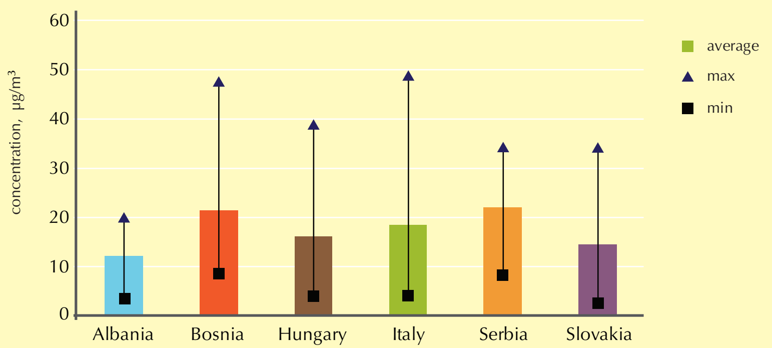


Figure 7

Four-day concentrations of indoor FORMALDEHYDE measured in the classrooms in the SEARCH countries.

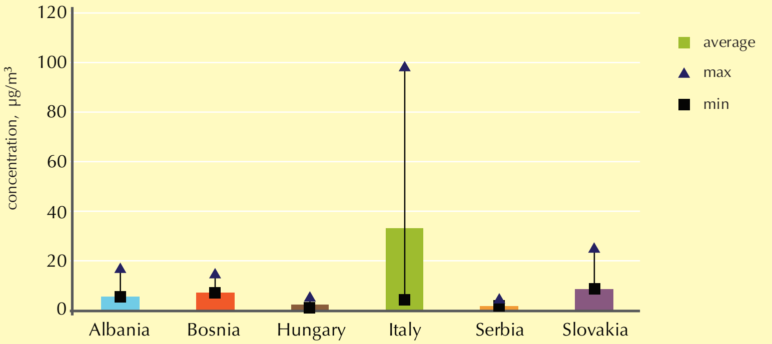
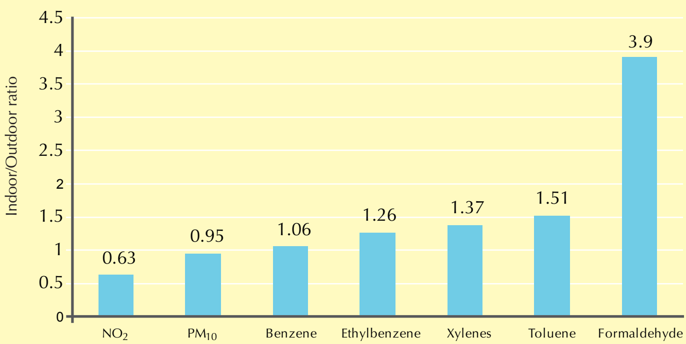


Figure 8

Relationships of indoor/outdoor concentrations measured in the classrooms and outside the schools.



4.2 Results of the pooled analysis of data from six countries

Introduction

In principle, 3 main groups of school environment are worth analysing the associations with the children's health:

1. the close neighbourhood of the schools and the position and orientation of the classes;
2. the possible sources of indoor air pollutants within the classrooms (including furniture, wall and floor coverings and cleaning practice);
3. the occupancy of the classrooms and ventilation

4.2.1 The close neighbourhood of the schools, position and orientation of the classes, the measured concentrations of indoor air pollutants and their associations with the respiratory health of children

Traffic

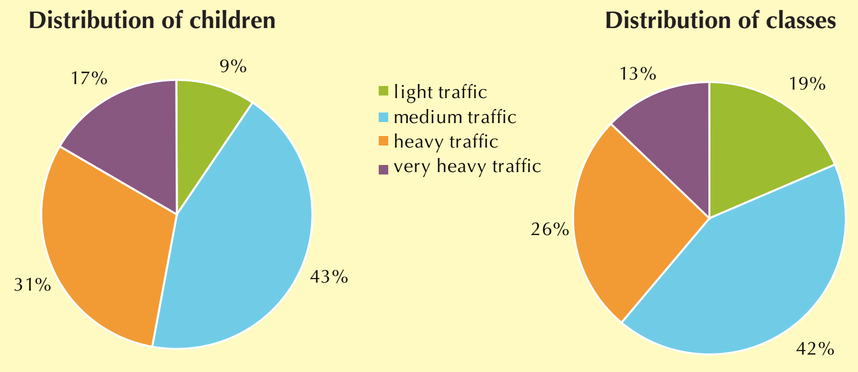
The distribution of pupils and the studied classrooms of schools with various traffic density is presented in *Figure 9*. Almost half (48%) of the investigated children go to school located either in a heavy traffic area (31%) or in a very heavy traffic area (17%). Comparison of the two distributions reveal that the classrooms in the heavy or very heavy traffic areas are much more crowded than the classrooms in the schools with light or medium traffic density.

In most countries outdoor PM_{10} concentrations were significantly higher in areas with very heavy traffic than in those with light traffic. However this difference was not reflected in the indoor PM_{10} concentrations measured in the classrooms suggesting that besides the outdoor PM_{10} level indoor sources have also to be counted for. Indoor nitrogen-dioxide (NO_2) and benzene were also measured in significantly higher concentrations in the schools of very heavy traffic areas than in light traffic areas.

Concentrations of pollutants measured in the classrooms in very heavy traffic areas varied according to the orientation and the floor level of the classroom. E.g. benzene level was found in significantly higher concentrations in classrooms facing the street and above the 2nd floor in very heavy

Figure 9

Distribution of children and classes of schools located in areas with various traffic density



traffic areas. It is worth mentioning that in light traffic areas there was no classroom above the 2nd floor.

Children exposed to higher levels of benzene were found to suffer more frequently from waking up by wheeze at night, a kind of frightening asthmatic symptom. *(Figure 10.)* The crude association was highly significant ($p<0.001$), and even after adjustment to known confounders (country, age, gender, asthma of the parents and smoking during pregnancy) the association remained significant (Odds Ratio, OR=1.44, 95% confidence interval, C.I.:1.03-2.01; p=0,032)

Logistic regression analyses of logarithmic concentrations of indoor PM_{10} revealed that PM_{10} was significantly associated with some reported bronchitic symptoms, especially usual cough during day and night (OR=1.23; 95% C.I.:1.001-1.51) and reported attention deficit (OR=1.31; 95% C.I.: 1.02-1.69), after adjustments to age, gender and country. There was a significant increase of risk for usual cough during day and night at indoor concentrations above a cut-off point of 80 microgram/m^3 of PM_{10} *(Figure 11.)* Lung function results showed similar effect: both FEV_1 (forced expiratory volume of air in 1 sec.) and PEF (peak expiratory flow) values were significantly decreased in children exposed to PM_{10} above 80 $\mu g/m^3$.

Figure 10

Prevalence (%) of children woken up by wheeze at night and mean benzene concentrations measured in the classroom

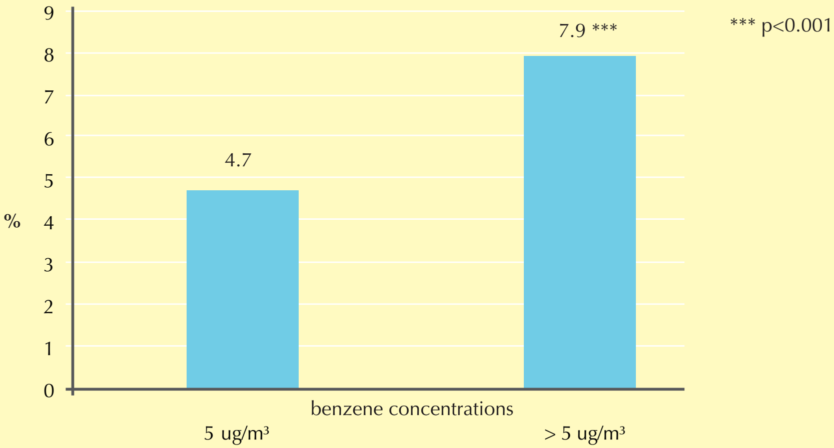
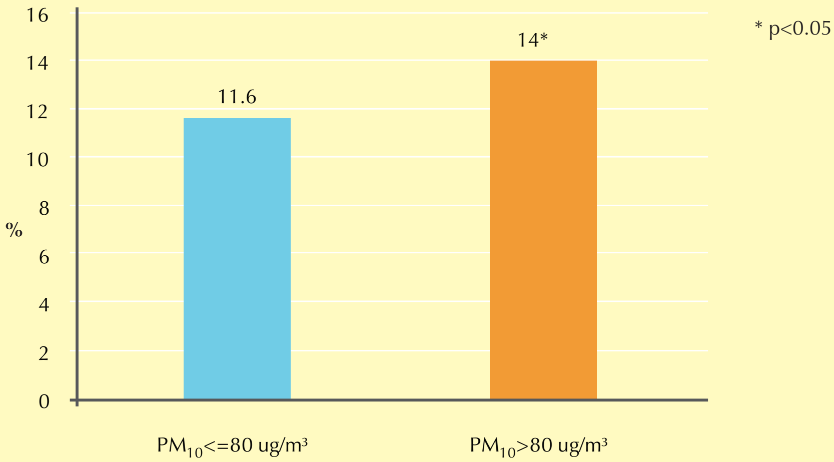


Figure 11

Prevalence of children (%) with or without regular day/night cough in classes with PM_{10} concentrations <80 µg/m³ or above



Polluting establishments in the neighbourhood

The distribution of children in schools with polluting establishments within a distance of 500 meter is presented in *Figure 12.* Every seventh child went to school exposed to emissions of some kind of industrial activity.

In some countries the concentrations of NO_2, benzene and xylenes were significantly higher in the schools near an industrial establishment. No similar differences could be observed in the case of formaldehyde, toluene and carbon-dioxide.

Figure 12

Percentage of children in schools with polluting establishments in the neighbourhood

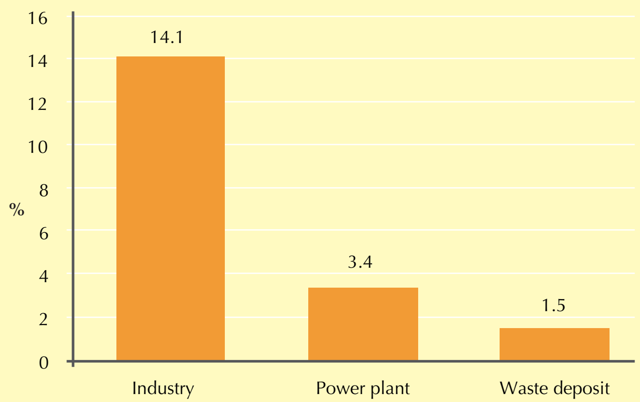
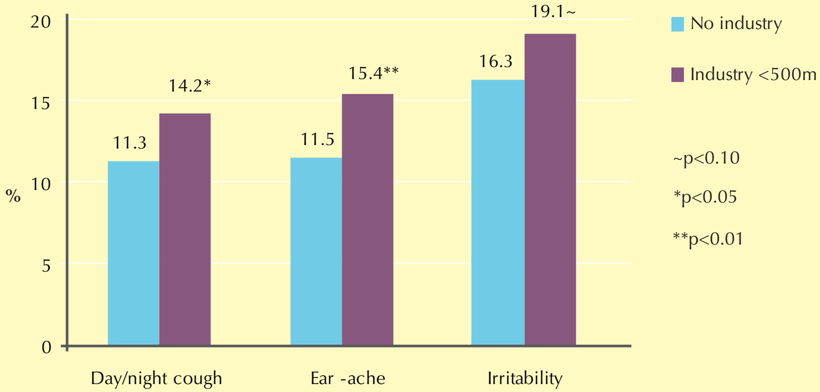


Figure 13. presents the prevalence of children with reported physical and psychic symptoms found to be associated with the presence of industry within 500 meters from the school. After adjustment to age, gender, country and industry close to the home, the adjusted Odds Ratios and their 95% Confidence Intervals were 1.35 (1.03-1.76) for usual day/night cough during the autumn/winter season, 1.35 (1.06-1.72) for ear-ache for at least two weeks during the last 6 months, and 1.35 (1.06-1.72) for increased irritability during the last 6 months. Lung function results showed significant decrease of FEV1 and PEF values in children visiting schools with industry in the close neighbourhood.

Figure 13

Prevalence (%) of children with physical and psychic symptoms in schools with or without industry in the neighbourhood



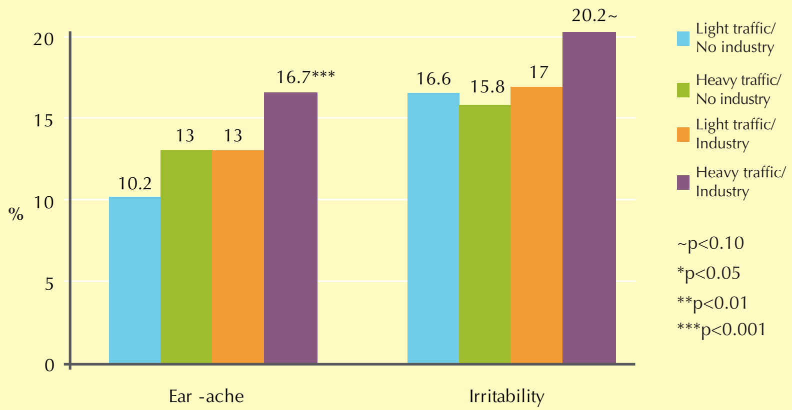
Traffic and industry together

Although some pollutants (benzene and xylenes) were found in increased levels in areas with both very heavy traffic and industry in the neighbourhood, their concentrations did not reflect any interaction between the various types of pollution sources. However, in most countries the concentrations of PM_{10} and NO_2 showed some interrelationship between the polluting activity of industry and traffic where the impact of industry seemed to be more substantial.

Among the studied health outcomes, the prevalence of ear-ache and increased irritability as well as lung function test results (FEV_1 and PEF) showed significant associations with the presence of both industry and heavy traffic in the close neighbourhood of the schools. (*Figure 14.*) After adjustment to age, gender, country and crowdedness, industry in the neighbourhood was the most powerful determinant of both ear-ache (OR= 1.51; 95% C.I.: 1.12-2.04, p=0.007) and irritability (OR=1.59; 95% C.I.: 1.21-2.10; p=0.001).

Figure 14

Prevalence of children with ear-ache or irritability in schools with industry and/ or heavy traffic around



4.2.2 Possible sources of indoor air pollutants within the classrooms

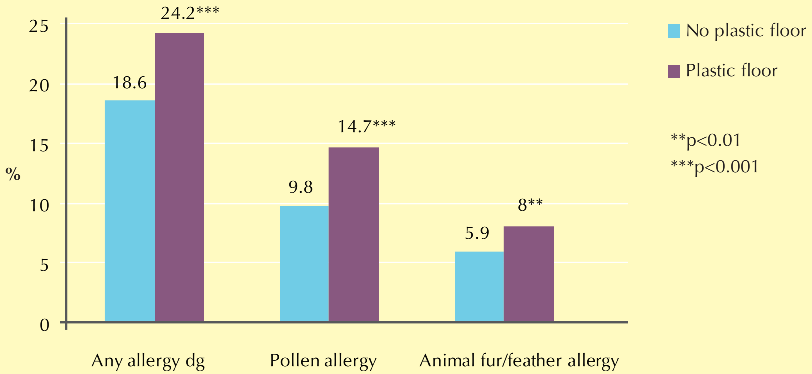
Floor coverings

Plastic floor in the classrooms: 38.8% of the children were staying in classrooms with plastic floor coverings. No relevant pollutant was found to be associated with the presence of plastic floor. Out of the studied health endpoints some types of aero-allergies diagnosed by a physician were significantly associated with plastic floor in the classrooms *(Figure 15.)* After adjustment to age, gender, country and plastic floor at home, the adjusted ORs and their 95% C.I.s were: 1.43 (1.07-1.92) for animal fur and feather allergy, 1.36 (1.09-1.70) for pollen allergy, and 1.33 (1.12-1.58) for any doctor-diagnosed allergies. There was also a significant decrease of FEV_1 values in children in classrooms with plastic floor.

Carpets in the classroom. 24.6% of the studied classrooms were fitted with carpets on the floor. In most countries the measured volatile organic

Figure 15

Prevalence of children with doctor-diagnosed allergies in classrooms with or without plastic floor



compounds (benzene, ethylbenzene, toluene, xylenes) and NO_2 were found in significantly higher concentrations in classrooms with carpet on the floor than in those without it. PM_{10} and formaldehyde did not show similar patterns.

In spite of the multiple associations between the presence of carpet on classroom floor and the measured VOC concentrations, bivariate analyses between floor carpet and the various health outcomes did not reveal any significant associations. However, after adjustment to age, gender, country, benzene and floor-carpet at home, there was a significant association with the prevalence of children **woken up by wheeze** at night as shown earlier in *Figure 10.* (OR=1.64; 95% C.I.: 1.12 – 2.41). In this case, benzene category of >5µg/m^3 was also significantly associated with the mentioned asthmatic symptom (OR=1.59; 95% C.I.: 1.16 – 2.18), independently from the presence of floor carpet. It means that both benzene category of >5µg/m3 and presence of floor carpet in the classroom were independent determinants of waking up the children by wheeze at night, a serious asthmatic symptom.

Wall coverings

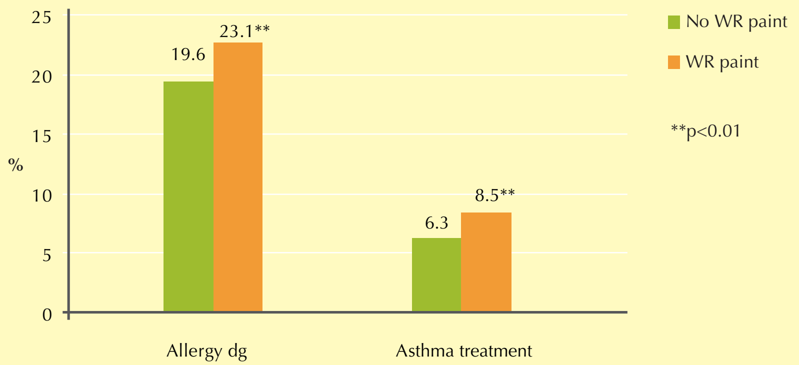
More than two-thirds of the walls of the studied classrooms were painted with water-soluble paints and there was no association observed either with increased level of any measured pollutants or with any adverse health outcomes.

Water resistant paints. 29.5% of the classrooms were painted with water-resistant paints. In most countries the measured concentrations of benzene, ethyl-benzene and xylenes were significantly higher in these classrooms than in those painted with water-soluble paints. These differences were significant independently from the time elapsed since the renewal.

Children staying in classrooms with walls painted with water-resistant paints were more likely to have allergy diagnosed by a physician or treated for asthma during the last 12 months than children staying in classrooms with walls painted with water-soluble paints. *(Figure 16.)* After adjustment to age, gender, country and synthetic wall paint at home, the adjusted odds ratios and their 95% confidence intervals were: 1.42 (1.10-1.83) for asthma treatment and 1.18 (1.004-1.39) for doctor-diagnosed allergy.

Figure 16

Prevalence of children with doctor-diagnosed allergy or recently treated for asthma visiting classrooms with wall painted with water resistant (WR) paints



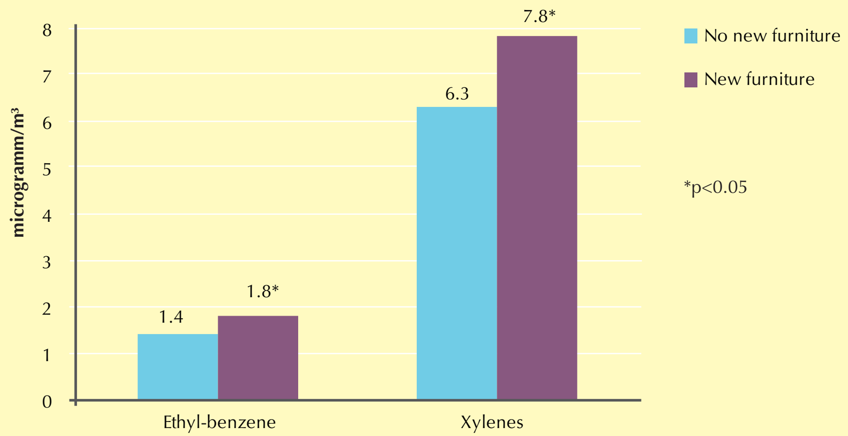
Furniture and blackboard

The classroom questionnaire inquired about the time elapsed since new furniture was installed. Increased concentrations of ethyl-benzene and xylenes were measured in classrooms where new furniture was installed during the last twelve months (in 7.7% of the classes). *(Figure 17.)*

More than 95% of the classrooms used blackboard or greenboard with chalk, and 4.3% used white board with alcohol-based markers. This kind of distribution makes the interpretation of the results very difficult therefore the results are not detailed. It is worth to note, however, that the use of white board with alcohol-based markers was not associated with increased concentrations of any of the measured pollutants.

Figure 17

Mean concentrations of ethyl-benzene and xylenes in classrooms with or without new furniture



Cleaning practice

Cleaning frequency

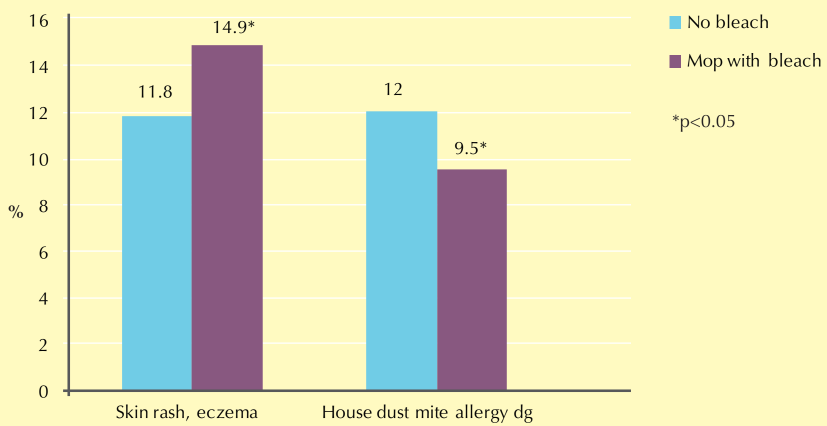
Somewhat less than half of the studied classrooms were cleaned twice a day and the others once a day. With the exception of formaldehyde, no other measured pollutants had lower concentrations in the classrooms cleaned twice a day than those cleaned once a day. However, sinusitis and/or ear-ache was found to be more likely among children in classrooms cleaned only once (adjusted OR=1.35; 95% C.I.: 1.08-1.69)

Cleaning instruments

Use of *vacuum cleaner* (13.4%) was not observed to be associated with changes in the concentrations of any pollutants measured during the teaching time. Concentrations of NO_2, and benzene were significantly lower in classrooms where *broom* (74.3%) and/or *mop* (69.3%) was used for cleaning. On the other hand, broom use was significantly associated with usual cough with phlegm during the autumn-winter seasons (adjusted OR=1.32; 95% C.I.: 1.01-1.72), and any of the 3 depression symptoms (fatigue, sleep disorders and reservedness), for which the adjusted OR was 1.24; with 95% C.I. of 1.03-1.50. In 8.3% of the classrooms the windows were generally not open during cleaning (independently from using vacuum cleaner or broom). Mop use was also associated with the prevalence of chronic conjunctivitis (adjusted OR=1.64; 95% C.I.: 1.15-2.33) and the 3 depression symptoms mentioned (aOR=1.31; 95% C.I.: 1.08-1.60).

Figure 18

Prevalence of children with skin rash and doctor-diagnosed house-dust mite allergy among children in classrooms cleaned with bleach



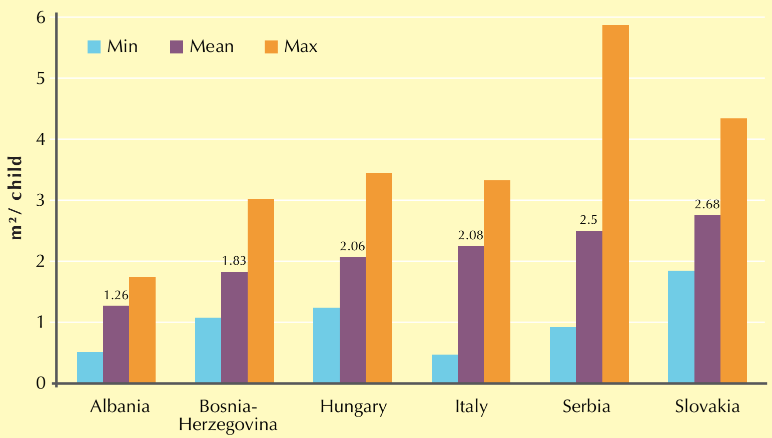
In 18% of the classrooms *mop with bleach* was used. Among children visiting these classrooms the risk of skin rash and eczema was found to be increased compared to children in other classrooms. (After adjustment to age, gender and country, the OR was 1.26 with 95% C.I. of 1.00-1.59.) On the other hand, the prevalence of doctor-diagnosed house-dust mite allergy was significantly lower among these children (adjusted OR: 0.73; 95% C.I.: 0.56-0.94). *(Figure 18.)*

4.2.3 Occupancy of the classrooms and ventilation

The mean (as well as the maximum and minimum) floor surface area per child by country is presented in *Figure 19*. As it may be seen from this figure, there are substantial differences in the floor surface area among countries. In order to avoid bias due to misclassification, for each country three individual floor area categories were constructed covering the lower (not crowded) and upper 25-30% (crowded) and the middle 40-50% (moderately crowded). Carbon-dioxide (CO_2), benzene and PM_{10} concentrations were found significantly increased with increasing crowdedness.

Figure 19

Mean, maximum and minimum floor surface area per child by country



Out of the analysed health outcomes, the reported prevalence of chronic ear-ache was significantly associated with the increased level of crowdedness (adjusted OR=1.33; 95% C.I.: 1.04-1.70).

Natural ventilation

It is obvious that moving activities of the children in the classrooms result in higher concentrations of pollutants. Therefore regular ventilation is very important for maintaining good indoor air quality. 70% of the classrooms were ventilated every break by opening the windows. However, 30% were ventilated less frequently. The typical indoor air pollutants like CO_2 and formaldehyde were found in significantly higher (by 61% and 165% higher, respectively) concentrations in the poorly ventilated classrooms, while the concentrations of others, like PM_{10} and NO_2 were by 17% and 23%, respectively, lower in these premises. The poor efficiency of ventilation was more obvious in the classrooms with increased crowdedness. *(Figure 20.)*

Most of the analysed respiratory symptoms were significantly associated with poor ventilation of the classrooms. *(Figure 21.)*

Figure 20

Concentration ratios (relative to the lowest category of crowdedness) of some pollutants by crowdedness categories and ventilation

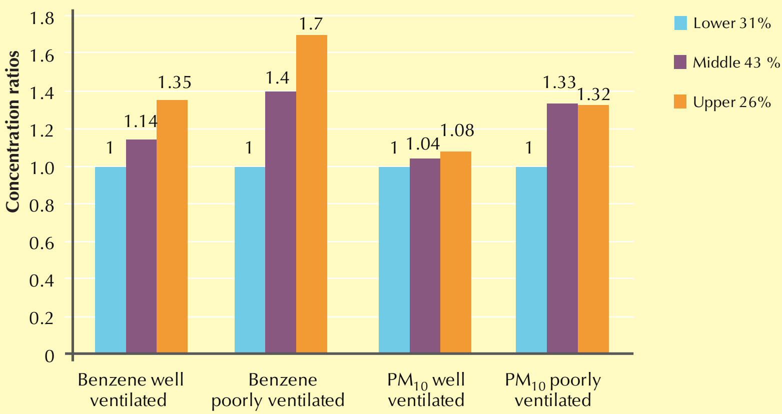
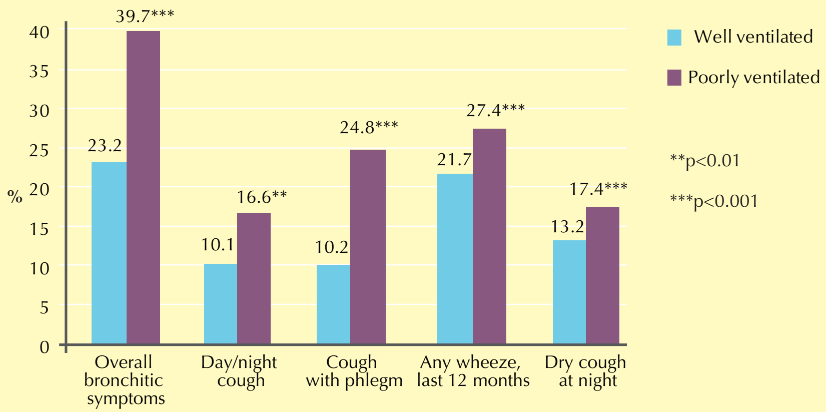


Figure 21

Prevalence of children with chronic respiratory symptoms in well or poorly ventilated classrooms



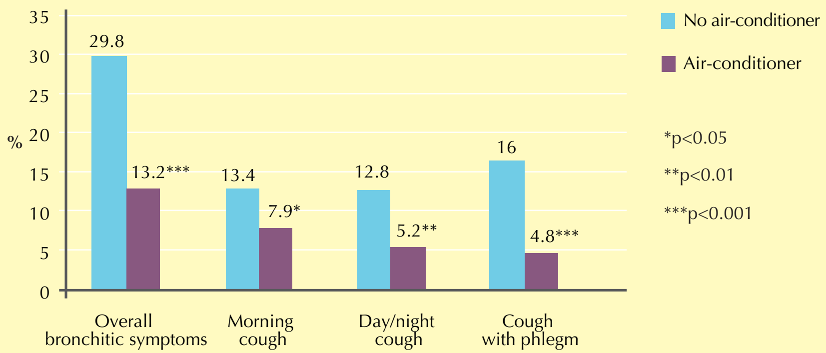
Air conditioners

There were some schools equipped with air conditioners in 3 countries (Bosnia-Herzegovina, Serbia and Slovakia). Air cleaning effectiveness was significant for CO_2 (1347 µg/m3 *vs.* 1913 µg/m3, p<0.001) and PM_{10} (66.3 µg/m3 vs. 79.7 µg/m3, p=0.0052), while all VOCs were measured in higher concentrations in these classrooms than in those without air conditioner.

Use of air conditioner was significantly associated with decreased risks for chronic bronchitic symptoms *(Figure 22.)*. After adjustment for age, gender and country, this protective effect remained statistically significant. On the other hand, significantly increased risk of sinusitis was observed in Bosnia-Herzegovina (9.8% vs. 4.2%, p=0.041, aOR= 2.51; 95% C.I.: 1.00-6.32, p= 0.05) while in the other two countries no similar result was found.

Figure 22

Prevalence of children with chronic bronchitic symptoms in classrooms with or without air conditioners



V. CONCLUSIONS

5.1 Site of the school

- *Heavy traffic* in the close neighbourhood of the school had an adverse effect on the children's exposure to most of the measured pollutants
- *Industry* in the close neighbourhood of the school had an adverse effect on the children's exposure to most of the measured pollutants, too.
- *Both heavy traffic and industry* in the close neighbourhood of the school were significant determinants of decreased lung function.

5.2 Sources of indoor air pollutants in the classroom

- *Plastic floor* in the classroom was associated with increased prevalence of doctor-diagnosed allergies and decreased lung function.
- Increased levels of the measured volatile organic compounds and nitrogen-dioxide were found in classrooms with *carpets on the floor* and these classrooms were associated with increased prevalence of children with woken up by wheeze at night.
- Increased levels of benzene, xylenes and ethylbenzene were measured in classrooms painted with *water-resistant paints* and these classrooms were associated with increased prevalence of allergies diagnosed and treated by a physician during the last 12 months.
- Increased levels of ethylbenzene and xylenes were measured in classrooms with *new furniture* installed during the last 12 months.
- *Broom use* for cleaning the classrooms was associated with increased prevalence of children with chronic cough with phlegm.
- *Use of mop* for cleaning was found to be associated with increased prevalence of reported chronic conjunctivitis.
- Use of mop with *bleach* was associated with increased prevalence of skin rash and eczema.

- Increased levels of ethylbenzene and xylenes were measured in classrooms with *closed windows during cleaning*.

5.3 Occupancy of the classroom and ventilation

- *Crowdedness* was associated with increased levels of carbon-dioxide (CO_2), PM_{10} and benzene measured in the classrooms as well as with higher prevalence of chronic ear-ache among children.
- *Poor natural ventilation* during teaching hours was associated with increased levels of CO_2 and formaldehyde measured in the classrooms and with increased prevalence of chronic bronchitis and asthmatic symptoms.
- Decreased prevalence of chronic bronchitis was found among children visiting classrooms equipped with *air conditioner*

VI. RECOMMENDATIONS

- Schools should be built in places not directly affected by heavy traffic or industry or any other polluting establishments in the neighbourhood.
- Crowdedness should be avoided in the classrooms.
- Appropriate ventilation regime of the classrooms should be introduced in order to provide good indoor air quality during the whole period of teaching hours.
- Floor coverings of the classrooms should be chosen with particular cautiousness to avoid any adverse effects on the respiratory health of children.
- Use of water-resistant paints in the classrooms should be avoided.
- Clear instructions for good cleaning practice in schools should be provided and appropriate control should be exerted over their implementation.
- New preventive and legal measures, and criteria for controlling indoor air quality with special attention to various allergies should be introduced in the European schools.
- Capacity building and awareness raising programmes should be organised in the European schools to promote the healthy school environment.

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VIII. PLANTS

The following indoor plants are the most effective to remove air pollutants

Areca Palm
(Chrysalidocarpus lutescens)

Azalea

Bronze Banana
(Musa ornata)

Chrysanthemum

Devils Ivy
(Scindapsus aureus)

Dracena marginata

Chinese Evergreen
(Aglaonema modestum)

Ferns

Weeping Fig
(Ficus benjamina)

Gerbera Daisy

Ivy (Hedera helix)

Mother-in-Law-Tongue
(Sansaviera)

Spatiphyllum

Spider Plant
(Chlorophytum comosum)

POLLUTION SOURCES	SOLUTIONS
Formaldehyde	
Foam Insulation	Philodendron
Plywood	Spider Plant
Clothes	Golden Pothos
Carpeting	Bamboo Palm
Furniture	Corn Plant
Paper Goods	Chrysanthemum
Household Cleaners	Mother-in-Law-Tongue
Benzene	
Tobacco Smoke	English Ivy
Gasoline	Dracena Marginata
Synthetic Fibers	Janet Craig
Plastics	Chrysanthemum
Inks	Gerbera Daisy
Oils	Warneckii
Detergents	Peace Lily

Trichloroethylene

Dry Cleaning	Gerbera Daisy
Inks	Chrysanthemum
Paints	Peace Lily
Varnishes	Warneckii
Lacquers	Dracena Marginata

Source: Research undertaken by the National Aeronautics and Space Administration (NASA)