School Environment and Respiratory Health of Children (SEARCH)

International research project report within the programme “Indoor air quality in European schools: Preventing and reducing respiratory diseases”

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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 to 2010. There are two associated countries in the project: Austria and Norway.

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

More than five years have 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 an example of 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 outdoor 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 and civil society organisations, 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, environment and health research institutes, environmental and health authorities, schools, and 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 Italian-Hungarian initiatives on indoor air quality in schools to other European countries.

The Hungarian Ministry of Health provided additional support for researchers from 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 were consult on the project design, the environmental and health data analysis, and the conclusions and recommendations.

The Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management; the Norwegian Ministry for the Environment; and the Norwegian Institute for Air Research (NILU) are supporters from the associated countries.
II. DESCRIPTION OF THE SEARCH PROJECT

2.1 Background

The SEARCH project is built on the 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 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, experts from the National Environmental Health Institute of Hungary found that the outdoor and indoor environment of schools, the standard of living of families and parental attitudes to childhood health issues determine the incidence of respiratory disease among students.

The capacity building of 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 (i.e. how to clean the classrooms).

The first chapter of the training material lists the harmful substances found in schools and emphasises 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. (E. Csobod, J. Heszlenyi and A. Schroth: Improving Indoor Air Quality in Schools, 2004, REC, Hungary, www.rec.org/SEARCH)
Due to the successful outcome of the pilot project described 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. The 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 main objectives of the SEARCH project are:

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

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

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 schools;
   b.) assessment of the school building and maintenance; and
   c.) assessment of the home environment.
2. Assessment of children’s health status:
   a.) symptom questionnaire; and
   b.) measurements of lung function.

3. Finding associations between school environment and children’s health based on analysed data from the project.

2.4. Implementation of the SEARCH project (2006-2010)

There are two parts to the project implementation: (I) Environmental and health assessment; and (II) Capacity building and awareness raising, 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 among 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 on 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 air quality). Preparation of the symptom questionnaire to collect information about the health condition of children (1,000 children/country).

II. Capacity building and awareness raising

1. Development and implementation of the publication “Indoor air quality training programme 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, data collection**

1. Measurement of selected indoor air pollutants in certain areas in the selected schools (Nov 2007-May 2008). Equipment for the measurement was discussed by the expert team from the countries (www.rec.org/SEARCH). The 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 (1,000/country). The final questionnaire was discussed with the country representatives and the expert team of the project before translation into national languages.

**II. Capacity building and awareness raising**

1. Launch of 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.

2. Finalisation and publication of 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 children’s health.

2. Reporting the results of the assessment at national and international events and consultations.

**II. Capacity building and awareness raising**

1. Preparation of reporting on the outcome of the indoor air quality training programme for the side event to the 5th Environment and Health Ministerial Conference in Italy.
2. Reports from schools about the revised school development plans, including environment and health aspects, to improve indoor air quality in the schools.

3. Dissemination of training materials to other schools in eight countries to introduce the indoor air quality training concept, and sharing the experiences of the schools.

**2010**

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

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

3. Evaluation of the use of the training materials in European countries.
III. RESEARCH ACTIVITIES PERFORMED

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:

1. Analysis of the association between the environmental and health data obtained from the approximately 6,000 questionnaires on children’s health, schools and classrooms in Albania, Bosnia and Herzegovina, Hungary, Italy, Serbia and Slovakia.

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

The Department of Air Hygiene within the NIEH was responsible for planning, preparing and coordinating the technical aspects of the air quality measurements, collecting the measurement results, organising, and partly carrying out, the analysis of the samples for all participating countries, and evaluating the Hungarian air pollution data.

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

Formaldehyde (HCHO), VOCs (benzene, toluene, ethyl-benzene and xylenes), carbon-monoxide (CO), nitrogen dioxide (NO₂), respirable particulate matter (PM₁₀) and carbon dioxide (CO₂), as the most commonly measured compounds, and the two characteristic indoor air parameters temperature (T) and relative humidity (RH) were monitored inside each classroom. In Hungary, 43 classrooms in 10 schools were incorporated in the programme.

A combination of diffusive sampling (HCHO, NO₂ and VOCs) with four-day exposure time; and continuous monitoring (CO, CO₂, PM₁₀ and T and RH) for one day during the teaching period was conducted in each classroom.

In parallel, outdoor air pollution was also controlled.

Additional information about the location of the classroom, its capacity, ventilation and heating system, furnishing, flooring, wall-covering, type and use of windows and other data were 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 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

4.1 Classroom characteristics and the indoor air pollutants

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

<table>
<thead>
<tr>
<th>Classroom characteristics</th>
<th>Pollutants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of children in the classroom &gt;20</td>
<td>Increased level of toluene</td>
</tr>
<tr>
<td>Classroom facing the street</td>
<td>Increased levels of PM$_{10}$ and CO$_2$</td>
</tr>
<tr>
<td>Classroom floor: wood</td>
<td>Increased levels of PM$_{10}$, benzene, ethylbenzene, toluene, xylenes, total BTEX and formaldehyde</td>
</tr>
<tr>
<td>Classroom wall painted with water-resistant paint</td>
<td>Increased levels of benzene, toluene, ethylbenzene, xylenes, total BTEX, formaldehyde</td>
</tr>
<tr>
<td>Classroom wall renewal &lt; 1 year</td>
<td>Increased levels of ethylbenzene, xylenes, total BTEX</td>
</tr>
<tr>
<td>Classroom cleaning in the morning</td>
<td>Increased levels of xylene and total BTEX and formaldehyde</td>
</tr>
<tr>
<td>Classroom floor cleaned with a broom</td>
<td>Increased level of NO$_2$</td>
</tr>
<tr>
<td>Classroom floor cleaned with a mop</td>
<td>Increased level of toluene and total BTEX</td>
</tr>
</tbody>
</table>

Indoor air measurement data were obtained from 242 classes in schools in the six participating countries. Health data were provided for 5,242 children. Associations between the indoor air pollution 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 health indicators were assessed by logistic regression, adjusted for the gender and age of the children.
### 4.2 Classroom characteristics and health indicators

Classroom characteristics and health indicators significantly associated with the indoor pollutant levels measured in the six 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 six countries**

<table>
<thead>
<tr>
<th>Pollutants</th>
<th>Classroom characteristics</th>
<th>Health indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\text{CO}_2)</td>
<td>Classroom level &lt;br&gt; Number of children in the classroom &lt;br&gt; (&lt;2\text{m}^2/\text{person in the classroom}) &lt;br&gt; (&lt;6\text{m}^3/\text{person in the classroom}) &lt;br&gt; Openable window &lt;(2\text{m}^2) &lt;br&gt; Less frequent window opening</td>
<td>Bronchitic symptoms (chronic cough in the daytime, or (&gt;3) months, or with phlegm) &lt;br&gt; Woken up by wheezing at night</td>
</tr>
<tr>
<td>(\text{PM}_{10})</td>
<td>Frequent window opening &lt;br&gt; Classroom cleaning in the evening</td>
<td>Chronic morning cough &lt;br&gt; Attention deficit</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>Classroom cleaning in the evening</td>
<td>Bronchitic symptoms (especially cough with phlegm)</td>
</tr>
<tr>
<td>(\text{Total BTEX})</td>
<td>Classroom level &lt;br&gt; Number of children in the classroom &lt;br&gt; Plastic floor in the classroom &lt;br&gt; Carpet in the classroom &lt;br&gt; Classroom wall renewal &lt;(1\text{year}) &lt;br&gt; New furniture &lt;(1\text{ year})</td>
<td>Mould allergy &lt;br&gt; Skin rash &lt;br&gt; Sinusitis</td>
</tr>
<tr>
<td>Benzene</td>
<td>Classroom level &lt;br&gt; Number of children in the classroom &lt;br&gt; Carpet in the classroom</td>
<td>Woken up by wheezing</td>
</tr>
<tr>
<td>Toluene</td>
<td>Classroom level &lt;br&gt; Number of children in the classroom &lt;br&gt; (&lt;2\text{m}^2/\text{person in the classroom}) &lt;br&gt; (&lt;6\text{m}^3/\text{person in the classroom}) &lt;br&gt; Plastic floor in the classroom &lt;br&gt; Carpet in the classroom &lt;br&gt; Classroom wall renewal &lt;(1\text{year}) &lt;br&gt; New furniture &lt;(1\text{ year})</td>
<td>Mould allergy &lt;br&gt; Sinusitis</td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>Carpet in the classroom &lt;br&gt; Wall painted with water-resistant paint &lt;br&gt; New furniture &lt;(1\text{ year})</td>
<td>Diagnosed allergy &lt;br&gt; Drug allergy (diagnosed)</td>
</tr>
<tr>
<td>Xylenes</td>
<td>Carpet in the classroom &lt;br&gt; Wall painted with water-resistant paint &lt;br&gt; Classroom cleaning in the morning &lt;br&gt; New furniture &lt;(1\text{ year})</td>
<td>Diagnosed allergy</td>
</tr>
</tbody>
</table>
Carbon dioxide (CO$_2$) was a good marker of crowdedness in the classrooms, regardless of which indicator (number of children in the classroom, <2 m$^2$/person or <6 m$^3$/person in the classroom) was used and it reflected 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 respiratory diseases may be regarded as an indirect rather than a direct one. Volatile organic compounds are known to irritate the mucosa of the respiratory tract and may also cause allergies. These results, however, should be considered as preliminary and therefore interpreted with much caution.

### 4.3 Indoor air pollutants measured in the classrooms

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

**Table 3. Summary of the results of indoor air measurements in schools in the six SEARCH countries**

<table>
<thead>
<tr>
<th>Classroom characteristics</th>
<th>Albania</th>
<th>Bosnia and Herzegovina</th>
<th>Hungary</th>
<th>Italy</th>
<th>Serbia</th>
<th>Slovakia</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM$_{10}$ ($\mu$g/m$^3$)</td>
<td>69</td>
<td>102</td>
<td>56</td>
<td>82</td>
<td>81</td>
<td>80</td>
</tr>
<tr>
<td>Formaldehyde ($\mu$g/m$^3$)</td>
<td>5.61</td>
<td>7.13</td>
<td>2.41</td>
<td>33.07</td>
<td>1.73</td>
<td>8.71</td>
</tr>
<tr>
<td>Benzene ($\mu$g/m$^3$)</td>
<td>4.06</td>
<td>6.29</td>
<td>2.16</td>
<td>1.95</td>
<td>5.94</td>
<td>4.84</td>
</tr>
<tr>
<td>Toluene ($\mu$g/m$^3$)</td>
<td>15.45</td>
<td>27.58</td>
<td>4.56</td>
<td>5.01</td>
<td>21.94</td>
<td>29.47</td>
</tr>
<tr>
<td>Ethylbenzene ($\mu$g/m$^3$)</td>
<td>1.24</td>
<td>1.60</td>
<td>1.64</td>
<td>1.82</td>
<td>1.60</td>
<td>1.38</td>
</tr>
<tr>
<td>Xylenes ($\mu$g/m$^3$)</td>
<td>5.03</td>
<td>7.65</td>
<td>7.04</td>
<td>7.10</td>
<td>8.00</td>
<td>5.07</td>
</tr>
<tr>
<td>NO$_2$ ($\mu$g/m$^3$)</td>
<td>12</td>
<td>21</td>
<td>16</td>
<td>19</td>
<td>22</td>
<td>14</td>
</tr>
</tbody>
</table>
4.4. The prevalence of respiratory symptoms

The prevalence of respiratory symptoms among the participating children by country is shown in Table 4. and that of doctor-diagnosed allergies 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 analysing the associations between the various environmental factors and the health status of 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 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 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 six SEARCH countries

<table>
<thead>
<tr>
<th>Symptoms / diseases</th>
<th>Albania (n=1019)</th>
<th>Bosnia and Herzegovina (n=975)</th>
<th>Hungary (n=704)</th>
<th>Italy (n=915)</th>
<th>Serbia (n=733)</th>
<th>Slovakia (n=894)</th>
<th>Total (n=5,242)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morning cough</td>
<td>18.7</td>
<td>10.6</td>
<td>8.4</td>
<td>13.2</td>
<td>10.5</td>
<td>14.8</td>
<td>13.0</td>
</tr>
<tr>
<td>Day/night cough</td>
<td>20.8</td>
<td>9.7</td>
<td>6.5</td>
<td>11.8</td>
<td>9.9</td>
<td>11.0</td>
<td>12.1</td>
</tr>
<tr>
<td>Cough &gt;3 months</td>
<td>7.7</td>
<td>3.1</td>
<td>3.3</td>
<td>3.5</td>
<td>3.1</td>
<td>2.4</td>
<td>4.0</td>
</tr>
<tr>
<td>Cough with phlegm</td>
<td>41.6</td>
<td>11.9</td>
<td>3.6</td>
<td>8.5</td>
<td>9.4</td>
<td>4.8</td>
<td>14.4</td>
</tr>
<tr>
<td>ANY BRONCHITIC SYMPTOM</td>
<td><strong>53.6</strong></td>
<td><strong>24.7</strong></td>
<td><strong>13.4</strong></td>
<td><strong>22.8</strong></td>
<td><strong>21.5</strong></td>
<td><strong>24.4</strong></td>
<td><strong>28.0</strong></td>
</tr>
<tr>
<td>Wheezing in the last 12 months</td>
<td>6.5</td>
<td>9.2</td>
<td>8.2</td>
<td>11.5</td>
<td>9.4</td>
<td>8.2</td>
<td>8.8</td>
</tr>
<tr>
<td>Wheezing after exercise, &lt;12 ms</td>
<td>3.5</td>
<td>5.6</td>
<td>5.8</td>
<td>6.0</td>
<td>5.0</td>
<td>3.6</td>
<td>4.9</td>
</tr>
<tr>
<td>Dry cough at night, &lt;12 months</td>
<td>14.2</td>
<td>14.7</td>
<td>10.9</td>
<td>13.9</td>
<td>13.9</td>
<td>15.8</td>
<td>14.0</td>
</tr>
<tr>
<td>Woken up by wheezing &lt;12 months</td>
<td>7.4</td>
<td>5.3</td>
<td>2.0</td>
<td>3.6</td>
<td>6.0</td>
<td>5.6</td>
<td>5.1</td>
</tr>
<tr>
<td>ANY ASTHMATIC SYMPTOM</td>
<td>22.8</td>
<td>23.3</td>
<td>16.9</td>
<td>23.4</td>
<td>22.9</td>
<td>23.9</td>
<td>22.4</td>
</tr>
<tr>
<td>Doctor-diagnosed asthma, ever</td>
<td>11.8</td>
<td>11.2</td>
<td>7.1</td>
<td>12.2</td>
<td>12.8</td>
<td>7.1</td>
<td>10.5</td>
</tr>
<tr>
<td>Asthma treatment, last 12 months</td>
<td>5.7</td>
<td>7.2</td>
<td>3.7</td>
<td>7.9</td>
<td>9.3</td>
<td>6.3</td>
<td>6.7</td>
</tr>
</tbody>
</table>

**Table 5. Prevalence (%) of doctor-diagnosed allergies among the participating children in the six SEARCH countries**

<table>
<thead>
<tr>
<th>Allergies</th>
<th>Albania</th>
<th>Bosnia and Herzegovina</th>
<th>Hungary</th>
<th>Italy</th>
<th>Serbia</th>
<th>Slovakia</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>House-dust mites</td>
<td>13.2</td>
<td>9.7</td>
<td>9.5</td>
<td>8.9</td>
<td>10.1</td>
<td>9.7</td>
<td>10.3</td>
</tr>
<tr>
<td>Animal fur, feather</td>
<td>4.9</td>
<td>4.9</td>
<td>9.7</td>
<td>4.4</td>
<td>5.6</td>
<td>6.6</td>
<td>5.8</td>
</tr>
<tr>
<td>Pollen</td>
<td>5.9</td>
<td>9.6</td>
<td>12.2</td>
<td>8.9</td>
<td>11.8</td>
<td>14.8</td>
<td>10.3</td>
</tr>
<tr>
<td>Mould</td>
<td>5.1</td>
<td>3.4</td>
<td>7.2</td>
<td>3.2</td>
<td>4.1</td>
<td>5.2</td>
<td>4.6</td>
</tr>
<tr>
<td>Food</td>
<td>5.3</td>
<td>2.6</td>
<td>8.8</td>
<td>4.9</td>
<td>2.6</td>
<td>5.8</td>
<td>4.9</td>
</tr>
<tr>
<td>Drug</td>
<td>5.0</td>
<td>4.1</td>
<td>10.8</td>
<td>3.4</td>
<td>4.5</td>
<td>4.6</td>
<td>5.2</td>
</tr>
<tr>
<td>ANY ALLERGY</td>
<td>19.4</td>
<td>17.5</td>
<td>23.7</td>
<td>17.5</td>
<td>17.4</td>
<td>28.5</td>
<td>20.6</td>
</tr>
</tbody>
</table>
4.5 Detailed results of air quality measurements

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 and 102 µg/m$^3$, although the maximum values were two to three times higher.

![Figure 1](image)

Concentrations of benzene measured over four days in the classrooms are presented in Figure 2. Average concentrations varied between 2.0 and 6.3 µg/m$^3$. In some classrooms in some countries, however, much higher concentrations were also measured.

The concentrations of toluene measured in the classrooms over four days are shown in Figure 3. Although average concentrations varied between 4.6 and 29.0 µg/m$^3$, in exceptional cases extremely high values were also measured.
Indoor benzene levels measured over four days in classrooms in SEARCH countries

Figure 2

Indoor toluene levels measured over four days in classrooms in the SEARCH countries

Figure 3
The concentrations of ethylbenzene measured over four days in the classrooms are presented in Figure 4. Average concentrations varied between 1.2 and 2.0 µg/m³, although, maximum values between two and five times (or even more) higher were also recorded.

![Figure 4](image)

Concentrations of xylenes measured over four days in the classrooms are presented in Figure 5. Average concentrations were in the range of 5 to 8 µg/m³, and maximum values were between 16 and 70 µg/m³.

Nitrogen dioxide concentrations measured over four days in the classrooms are shown in Figure 6. Average concentrations varied between 12.2 and 22.1 µg/m³ and even the maximum values were below 50 µg/m³.

Concentrations of formaldehyde measured over four days in the classrooms are presented in Figure 7. Average concentrations varied in the range of 2 to 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 NO₂ is ambient air, and that formaldehyde is primarily emitted by indoor emission sources.
Indoor levels of xylenes measured over four days in classrooms in the six SEARCH countries.

Levels of indoor nitrogen dioxide measured over four days in classrooms in the six SEARCH countries.
Concentrations of indoor formaldehyde measured over four days in classrooms in the six SEARCH countries

Relationship between indoor and outdoor concentrations measured in the classrooms and outside the schools
4.6 Results of the pooled analysis of data from the six countries

Introduction
In principle, three main aspects of the school environment are worth analyzing in association with children’s health:

1. the immediate neighbourhood of the schools and the position and orientation of the classrooms;
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.

4.6.1 The immediate neighbourhood of the schools, the position and orientation of the classrooms, 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 in schools with varying traffic density is presented in Figure 9. Almost half (48%) of the investigated children attend schools located either in a heavy traffic area (31%) or in a very heavy traffic area (17%). A comparison of the two distributions reveals that classrooms in heavy or very heavy traffic areas are far more crowded than classrooms in 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 accounted for. Indoor NO$_2$ and benzene were also measured in significantly higher concentrations in schools in very heavy traffic areas than in light traffic areas.

Concentrations of pollutants measured in classrooms in very heavy traffic areas varied according to the orientation and the floor level of the classroom. For example, benzene was found in significantly higher concentrations in classrooms facing the street and above the second floor in very
Children exposed to higher levels of benzene were found to suffer more frequently from waking up by wheezing at night, a 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 in the parents and smoking during pregnancy), the association remained significant (Odds Ratio, \( \text{OR}=1.44 \), 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 µg/m\(^3\) of PM\(_{10}\) (Figure 11). Lung function results showed similar effects: 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 µg/m\(^3\).
Figure 10

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

<table>
<thead>
<tr>
<th>Benzene Concentrations</th>
<th>% Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 µg/m³</td>
<td>4.7</td>
</tr>
<tr>
<td>&gt; 5 µg/m³</td>
<td>7.9 ***</td>
</tr>
</tbody>
</table>

*** p<0.001

Figure 11

Prevalence of children (%) with or without regular day/night cough in classrooms with PM₁₀ concentrations <80 µg/m³

<table>
<thead>
<tr>
<th>PM₁₀ Concentration</th>
<th>% Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤80 µg/m³</td>
<td>11.6</td>
</tr>
<tr>
<td>&gt;80 µg/m³</td>
<td>14*</td>
</tr>
</tbody>
</table>

* p<0.05
Polluting establishments in the neighbourhood

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

In some countries, concentrations of NO₂, benzene and xylenes were significantly higher in schools near an industrial establishment. No similar differences could be observed in the case of formaldehyde, toluene and CO₂.

Figure 13 shows the prevalence of children with reported physical and psychic symptoms found to be associated with the presence of industry within 500 metres of 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 six months, and 1.35 (1.06-1.72) for increased irritability during the last six months. Lung function results showed significant decrease of FEV1 and PEF values in children attending schools with industry in the close 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).
4.6.2 Possible sources of indoor air pollutants within the classrooms

Floor coverings

**Plastic flooring in the classrooms:** 38.8% of the children were taught in classrooms with plastic floor coverings. No relevant pollutant was found to be associated with the presence of plastic flooring. Out of the studied health endpoints, some types of aero-allergies diagnosed by a physician were significantly associated with plastic flooring in the classrooms (Figure 15). After adjustment to age, gender, country and plastic flooring 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 flooring.

**Carpets in the classroom.** 24.6% of the studied classrooms were fitted with carpets on the floor. In most countries the measured volatile organic
compounds (benzene, ethylbenzene, toluene, xylenes) and NO$_2$ were found in significantly higher concentrations in classrooms with carpeting 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 the classroom floor and the measured VOC concentrations, bivariate analyses between floor carpets and the various health outcomes did not reveal any significant associations. However, after adjustment to age, gender, country, benzene and carpeting on the floor at home, there was a significant association with the prevalence of children woken up by wheezing 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), independent of the presence of floor carpets. This means that both benzene category of >5µg/m³ and the presence of carpet flooring in the classroom were independent determinants of the children waking up by wheezing at night, a serious asthmatic symptom.
Wall coverings
The walls in more than two-thirds of the studied classrooms were painted with water-soluble paints and there was no association observed either with increased levels 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, ethylbenzene and xylenes were significantly higher in these classrooms than in those painted with water-soluble paints. These differences were significant, independent of the time that has elapsed since renewal.

Children taught in classrooms with walls painted with water-resistant paints were more likely to have an allergy diagnosed by a physician or to have been treated for asthma during the last 12 months than children taught 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 a doctor-diagnosed allergy or recently treated for asthma taught in classrooms with walls painted with water-resistant (WR) paints

<table>
<thead>
<tr>
<th></th>
<th>No WR paint</th>
<th>WR paint</th>
<th><strong>p&lt;0.01</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Allergy dg</td>
<td>19.6</td>
<td>23.1**</td>
<td></td>
</tr>
<tr>
<td>Asthma treatment</td>
<td>6.3</td>
<td>8.5**</td>
<td></td>
</tr>
</tbody>
</table>
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](image)

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

Cleaning practices

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 cleaners (13.4%) was not observed to be associated with changes in the concentrations of any pollutants measured during teaching time. Concentrations of NO$_2$ and benzene were significantly lower in classrooms where brooms (74.3%) and/or mops (69.3%) were 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 three 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 (independent of the use of 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 three depression symptoms mentioned (aOR=1.31; 95% C.I.: 1.08-1.60).

![Figure 18](image_url)

**Prevalence of children (%) with skin rash and doctor-diagnosed house-dust mite allergy in classrooms cleaned with bleach**

<table>
<thead>
<tr>
<th></th>
<th>No bleach</th>
<th>Mop with bleach</th>
<th>*p&lt;0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin rash, eczema</td>
<td>11.8</td>
<td>14.9*</td>
<td></td>
</tr>
<tr>
<td>House-dust mite allergy dg</td>
<td>12</td>
<td>9.5*</td>
<td></td>
</tr>
</tbody>
</table>
In 18% of the classrooms, a *mop with bleach* was used. Among children taught in these classrooms the risk of skin rash and eczema was found to be higher 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).

### 4.6.3 Occupancy of 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 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 to be significantly higher with increasing crowdedness.

![Figure 19](image-url)

*Figure 19*

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

- **Albania**: 1.26 m$^2$/child
- **Bosnia-Herzegovina**: 1.83 m$^2$/child
- **Hungary**: 2.06 m$^2$/child
- **Italy**: 2.08 m$^2$/child
- **Serbia**: 2.5 m$^2$/child
- **Slovakia**: 2.68 m$^2$/child
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 movement 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. Some 70% of the classrooms were ventilated every break by opening the windows. However, 30% were ventilated less frequently. The typical indoor air pollutants like CO₂ and formaldehyde were found in significantly higher (by 61% and 165% respectively) concentrations in the poorly ventilated classrooms, while the concentrations of others, like PM₁₀ and NO₂, were lower by 17% and 23% respectively 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 in the classrooms. (Figure 21).

![Figure 20](image-url)

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

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Lower 31%</th>
<th>Middle 43%</th>
<th>Upper 26%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene, well ventilated</td>
<td>1.14</td>
<td>1.4</td>
<td>1.35</td>
</tr>
<tr>
<td>Benzene, poorly ventilated</td>
<td>1</td>
<td>1.7</td>
<td>1.4</td>
</tr>
<tr>
<td>PM₁₀, well ventilated</td>
<td>1.04</td>
<td>1.08</td>
<td>1.33</td>
</tr>
<tr>
<td>PM₁₀, poorly ventilated</td>
<td>1</td>
<td>1</td>
<td>1.32</td>
</tr>
</tbody>
</table>
Air conditioners

There were some schools equipped with air conditioners in three countries (Bosnia and Herzegovina, Serbia and Slovakia). Air cleaning effectiveness was significant for CO$_2$ (1347 µg/m$^3$ vs. 1913 µg/m$^3$, p<0.001) and PM$_{10}$ (66.3 µg/m$^3$ vs. 79.7 µg/m$^3$, p=0.0052), while all VOCs were measured in higher concentrations in these classrooms than in those without air conditioning.

The use of air conditioning 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 and 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.
Prevalence of children (%) with chronic bronchitic symptoms in classrooms with or without air conditioners

<table>
<thead>
<tr>
<th>Condition</th>
<th>No air conditioner</th>
<th>Air conditioner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall bronchitic symptoms</td>
<td>29.8</td>
<td>13.2***</td>
</tr>
<tr>
<td>Morning cough</td>
<td>13.4</td>
<td>7.9*</td>
</tr>
<tr>
<td>Day/night cough</td>
<td>12.8</td>
<td>5.2**</td>
</tr>
<tr>
<td>Cough with phlegm</td>
<td>16</td>
<td>4.8***</td>
</tr>
</tbody>
</table>

*p<0.05  
**p<0.01  
***p<0.001
V. CONCLUSIONS

5.1 Site of the school

- *Heavy traffic* in the immediate neighbourhood of the school had an adverse effect on children’s exposure to most of the measured pollutants.

- *Industry* in the immediate neighbourhood of the school had an adverse effect on children’s exposure to most of the measured pollutants.

- *Both heavy traffic and industry* in the immediate neighbourhood of the school were significant determinants of decreased lung function.

5.2 Sources of indoor air pollutants in the classroom

- *Plastic flooring* in the classroom was associated with increased prevalence of doctor-diagnosed allergies and decreased lung function.

- Increased levels of the measured VOCs and NO₂ were found in classrooms with *carpets on the floor* and these classrooms were associated with an increased prevalence of children woken by wheezing 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 classrooms was associated with increased prevalence of children with a chronic cough with phlegm.

- *Mop use* for cleaning was found to be associated with the increased prevalence of reported chronic conjunctivitis.

- Mop use with *bleach* was associated with the increased prevalence of skin rash and eczema.
Increased levels of ethylbenzene and xylenes were measured in classrooms with *closed windows during cleaning*.

### 5.3 Classroom occupancy and ventilation

- *Crowdedness* was associated with increased levels of 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 conditioners*. 
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 classrooms.

- Appropriate ventilation regime in classrooms should be introduced in order to provide good indoor air quality during the whole period of teaching hours.

- Floor coverings in classrooms should be chosen with particular caution to avoid any adverse effects on the respiratory health of children.

- The use of water-resistant paints in 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 European schools.

- Capacity-building and awareness-raising programmes should be organised in European schools to promote a healthy school environment.
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VIII. PLANTS

The following indoor plants are the most effective in removing air pollutants

- Areca Palm
  (*Chrysalidocarpus lutescens*)

- Azalea

- Bronze Banana
  (*Musa ornata*)

- Chrysanthemum
Devil's ivy
(*Scindapsus aureus*)

Dracaena marginata

Chinese evergreen
(*Aglaonema modestum*)

Ferns
Weeping fig
(*Ficus benjamina*)

Gerbera daisy

Ivy
(*Hedera helix*)

Mother-in-law's tongue
(*Sansaviera*)
The harmony, the good atmosphere of schools, the balanced development of the children are connected to healthy school environment. It means the good indoor air quality, good quality of drinking water, the careful management of waste, careful selection of the cleaning materials, using plants in the school environment.

The most important question is that who should act in the schools?

The Capacity-building and Awareness-raising (II) part of the SEARCH project focuses on learning and action in the healthy schools. The Indoor air quality training program for teachers, students and the technical staff was developed in the SEARCH project to stimulate environment and health actions in the schools. The schools changed the design of the classrooms and used the plants (see in this chapter) to reduce the harmful indoor air substances.
Information about the most effective indoor air plants

<table>
<thead>
<tr>
<th>POLLUTION SOURCES</th>
<th>SOLUTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Formaldehyde</strong></td>
<td></td>
</tr>
<tr>
<td>Foam insulation</td>
<td>Philodendron</td>
</tr>
<tr>
<td>Plywood</td>
<td>Spider plant</td>
</tr>
<tr>
<td>Clothes</td>
<td>Golden pothos</td>
</tr>
<tr>
<td>Carpeting</td>
<td>Bamboo palm</td>
</tr>
<tr>
<td>Furniture</td>
<td>Corn plant</td>
</tr>
<tr>
<td>Paper goods</td>
<td>Chrysanthemum</td>
</tr>
<tr>
<td>Household cleaners</td>
<td>Mother-in-law’s tongue</td>
</tr>
</tbody>
</table>

| **Benzene**       |           |
| Tobacco smoke     | English ivy |
| Gasoline          | *Dracena marginata* |
| Synthetic fibre   | 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)
IX. REFERENCES


E. Csobod, J. Heszlenyi, A. Schroth: Improving Indoor Air Quality in Schools, 2004, REC, Hungary