Preliminary indoor and outdoor air pollution investigation in naturally ventilated classrooms: results from the ARIA project

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Scientific context

• Asthma and allergic diseases: important public health problems (300 M people in the World have asthma!).

• Children’s time indoors: home and school (~65% of the time at home!).

• School’s indoor air is also a health political priority (Parma Declaration, 2010).

• Few studies linking schools and home indoor environments and children’s health.
Objectives

as part of an ongoing ARIA project

to explore associations between various exposures that children, with detected evidence of respiratory disease, experience in indoor environments (specifically their homes and primary schools) and their well-being and health.

Preliminary findings from field studies in 10 primary schools in Porto, Portugal, in which physical, chemical and biological agents were characterized in 35 classrooms.
Material and methods

Sampling sites & study design

- Porto, Northern of Portugal
- 4 classrooms/school (total=10 schools, 35 classrooms)
- 1 outdoor/school
- Winter time (January-March 2014)
- Occupation period only (recess periods not considered)
Material and methods

- **TVOC** [1]
- **Formaldehyde** [2]
- **PM$_{2.5}$** [3], **PM$_{10}$** [3], **UFP** [4]
- **CO$_2$** [5]
- **Temperature and RH** [5]
- **Bacteria and fungi** [6]

Indoor and outdoor sampling

Diffusive samplers and consecutive analysis

Optical light scattering [3]

Continuous logger [4]

Impaction and consecutive analysis [6]

Infrared non-dispersive sensor (CO2); Thermistor (T); Thin-film capacitive sensor (RH)

NIOHS 0800 and EN 13098 methods
## Material and methods

### Indoor and outdoor sampling

<table>
<thead>
<tr>
<th>IAQ Parameter</th>
<th>Method</th>
<th>Instrument</th>
<th>Analysis</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volatile organic compounds (VOC)</td>
<td>Passive diffusion</td>
<td>Tenax TA stainless steel tubes</td>
<td>GC-MS</td>
<td>1 school week (Monday to Friday)</td>
</tr>
<tr>
<td>Formaldehyde and acetaldehyde</td>
<td>Passive diffusion</td>
<td>Radiello passive samplers</td>
<td>HP-LC</td>
<td>1 school week (Monday to Friday)</td>
</tr>
<tr>
<td>PM10 and PM2.5</td>
<td>Gravimetry</td>
<td>SKC portable pumps coupled with PTFE filters</td>
<td>--</td>
<td>8 hours per sampling place</td>
</tr>
<tr>
<td>Ultrafine particles (UFP)</td>
<td>(Optical)</td>
<td>P-Track model 8525</td>
<td>--</td>
<td>8 hours per sampling place (1 min logging intervals)</td>
</tr>
<tr>
<td>Bacteria and fungi</td>
<td>NIOSH 0800 and EN 13098 methods</td>
<td>Merck Air Sampler MAS-100</td>
<td>Naked eye count with Fellers law correction</td>
<td>10 min per sampling place</td>
</tr>
<tr>
<td>Carbon dioxide (CO2)</td>
<td>Infrared non-dispersive sensor</td>
<td>TSI IAQ–CALCTM monitor (model 7545)</td>
<td>--</td>
<td>5 school days per classroom (Monday to Friday, 5 min logging intervals)</td>
</tr>
<tr>
<td>Relative humidity (RH)</td>
<td>Thin-film capacitive sensor</td>
<td>TSI IAQ–CALCTM monitor (model 7545)</td>
<td>--</td>
<td>5 school days per classroom (Monday to Friday, 5 min logging intervals)</td>
</tr>
<tr>
<td>Temperature</td>
<td>Thermistor</td>
<td>TSI IAQ–CALCTM monitor (model 7545)</td>
<td>--</td>
<td>5 school days per classroom (Monday to Friday, 5 min logging intervals)</td>
</tr>
</tbody>
</table>
Results - indoor concentrations

- Indoor VOCs usually originate from products used in occupancy-related activities such as cleaning products or in school artwork.

- Aldehydes can have their origin in wood-based furniture, cork ceilings or paint.

- Outdoor sources and indoor occupant activities, respectively, are suspected/pointed to be the main sources for the levels of PM$_{2.5}$ and PM$_{10}$ indoors.

- Outdoor emissions significantly contributed to UFP indoors.
• Insufficient ventilation, as indicated by CO₂ levels, appears to be a common IAQ problem for almost all the schools (median levels above 1000 ppm).
• Importance of occupant behaviours in the control and guarantee of good IAQ, using CO₂ as a proxy.

• No comparisons can be made in relation to WHO guidance and EU limit values. Only in very few countries guidance values have been established (e.g. Portugal).
• Median concentration of bacteria higher than 1000 CFU/m³!
### Results - indoor/outdoor ratios

<table>
<thead>
<tr>
<th>Parameters</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
<th>S6</th>
<th>S7</th>
<th>S8</th>
<th>S9</th>
<th>S10</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>TVOCs</td>
<td>11.1</td>
<td>2.3</td>
<td>2.6</td>
<td>2.6</td>
<td>1.2</td>
<td>3.2</td>
<td>1.9</td>
<td>1.1</td>
<td>1.2</td>
<td>0.7</td>
<td>1.6</td>
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<tr>
<td>Formaldehyde</td>
<td>10.9</td>
<td>2.5</td>
<td>11.4</td>
<td>18.6</td>
<td>4.3</td>
<td>9.9</td>
<td>8.1</td>
<td>11.5</td>
<td>11.4</td>
<td>22.2</td>
<td>9.2</td>
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<tr>
<td>Acetaldehyde</td>
<td>20.7</td>
<td>4.6</td>
<td>15.9</td>
<td>18.7</td>
<td>1.7</td>
<td>6.9</td>
<td>2.4</td>
<td>3.1</td>
<td>6.8</td>
<td>17.7</td>
<td>5.4</td>
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<td>PM10</td>
<td>1.5</td>
<td>0.6</td>
<td>1.4</td>
<td>10.8</td>
<td>2</td>
<td>1.8</td>
<td>1.5</td>
<td>1.4</td>
<td>3</td>
<td>3.4</td>
<td>1.8</td>
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<tr>
<td>PM2.5</td>
<td>1.6</td>
<td>0.4</td>
<td>1.7</td>
<td>1.5</td>
<td>2.7</td>
<td>2.1</td>
<td>0.6</td>
<td>0.5</td>
<td>2.3</td>
<td>N/A</td>
<td>1.2</td>
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<tr>
<td>UFP</td>
<td>1.8</td>
<td>0.9</td>
<td>0.3</td>
<td>2.5</td>
<td>1.8</td>
<td>1.3</td>
<td>0.8</td>
<td>0.7</td>
<td>0.8</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Bacteria</td>
<td>6.2</td>
<td>12.1</td>
<td>32.8</td>
<td>42.5</td>
<td>16.3</td>
<td>704.8</td>
<td>30.3</td>
<td>42.3</td>
<td>2.3</td>
<td>1.8</td>
<td>7.2</td>
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<tr>
<td>Fungi</td>
<td>0.8</td>
<td>1.4</td>
<td>4.4</td>
<td>40</td>
<td>1.9</td>
<td>2.1</td>
<td>11.1</td>
<td>6.5</td>
<td>0.9</td>
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<td>5.3</td>
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<tr>
<td>CO2</td>
<td>6.7</td>
<td>3.5</td>
<td>3.7</td>
<td>6.1</td>
<td>4.9</td>
<td>2.5</td>
<td>2.6</td>
<td>3</td>
<td>5.9</td>
<td>8.1</td>
<td>4.5</td>
</tr>
</tbody>
</table>

- High I/O ratio (I/O>5): [d-limonene], CO$_2$, formaldehyde, acetaldehyde, bacteria, fungi
- Moderate I/O ratio (~2): TVOCs, [toluene], PM$_{10}$
- Low I/O ratio (I/O<1): PM$_{2.5}$, [benzene]
Final remarks

- CO$_2$, particulate matter and bacteria levels generally exceeded the established guidelines values.

- High CO$_2$ levels suggest poor ventilation in schools, which may be responsible for the increased concentrations of other pollutants.

- Opening the windows during school breaks may be a solution to overcome this problem.

- Exposure to indoor air is relevant to children’s health overall; exceedances of certain parameters (PM, CO$_2$, bacteria levels in classrooms) indicate the need to implement programs in order to further improve IAQ by, firstly, controlling pollutant sources.
Perspectives towards the future

• The ARIA project will study the tendencies of IAQ parameter concentrations associated with classroom and building characteristics.

• The results from the children’s clinical evaluation may further clarify the health risks of exposure to air pollutants in schools and their impact on the development of asthma and allergy.
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Assessment and determinants of airborne bacterial and fungal concentrations in different indoor environments: Homes, child day-care centres, primary schools and elderly care centres

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Thank you!

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