Improving Energy & IEQ Performance in Practice – case Indian Schools

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Two Different Kind of Schools

**Government Schools**
- 60 children per classroom
- Floor area 600 sq.ft.

**Private schools** (international & Indian)
- 30 children per classroom
- Floor area 600 sq.ft.
Current Energy and IEQ Performance: Private Schools

IAQ
- Thermal comfort: ⭐️⭐️⭐️⭐️⭐️
- Energy: ⭐️⭐️⭐️⭐️
- Lighting: ⭐️⭐️⭐️⭐️⭐️
- Acoustics: ⭐️⭐️
Current Energy and IEQ Performance: Government School

- **CO**
- **PM**
- **PM2.5**

![Diagram showing PM2.5 and CO levels in classrooms]

- **IAQ**: ★★★★☆
- **Thermal comfort**: ★★☆☆☆
- **Energy**: ★★★☆☆
- **Lighting**: ★★★☆☆
- **Acoustics**: ★☆☆☆☆

**PM2.5 Temperature**
Is CO₂ an Indoor Pollutant?

Direct Effects of Low-to-Moderate CO₂ Concentrations on Human Decision-Making Performance by State University of New York, Syracuse, and Lawrence Berkeley National Laboratory, Berkeley

Source: https://ehp.niehs.nih.gov/1104789/
Health Impacts of Poor IEQ

• Particulate matter and other pollutants present in indoor air, have a clear link with productivity, sense of wellbeing and occupant health. In long term, they lead to health hazards like asthma, allergies, headaches, respiratory diseases and cancer.

• Temperatures that are too high or too low, continuous high noise levels, or excessively bright or inadequate lighting level increase the stress levels in the human body, thus creating health issues like sleep disorder, digestive problems, memory and concentration impairment.
Pathological Changes in the Lungs

Healthy lungs  Outdoor air pollution exposure  Tobacco smoke

Source: Pathology slides - Courtesy Prof. Saldiva, São Paulo, Brazil
Productivity Research

Temperature (°C) vs. Relative Performance

Ventilation Rate (l/s-person) vs. Relative Performance
First Indoor Air Quality Problem of Human Being

170,000 years ago
Solution: Ventilation
Improved Energy and IEQ Performance: Private Schools

Ventilation
Filtration
5★ Rated Products

IAQ
Thermal comfort
Energy
Lighting
Acoustics
Improved Energy and IEQ Performance: Government Schools

Ventilation
Filtration
Evaporative Cooling

IAQ ★★★
Thermal comfort ★★
Energy ★★★
Lighting ★★
Acoustics ★★★★★

CO₂
PM₂.₅

Ventilation system with filters and CO₂ sensors.
Ventilation Rate

• Outdoor air as per ASHRAE 62.1: 10 cfm/person + 0.12 cfm/ft²

• Private school:
  – Outdoor air flow rate: \((30 \times 10)\ cfm + (600 \times 0.12)\ cfm = 372\ cfm (3\ l/s,m²)\)
  – Air change rate: \((372 \times 1.7)\ m³/h / (600 \times 0.093 \times 3)\ m³ = 3.8\ ac/h\)

• Government school:
  – Outdoor air flow rate: \((60 \times 10)\ cfm + (600 \times 0.12)\ cfm = 672\ cfm (5\ l/s,m²)\)
  – Air change rate: \((672 \times 1.7)\ m³/h / (600 \times 0.093 \times 3)\ m³ = 6.8\ ac/h\)
Good IAQ by Diluting Indoor Pollutants

Air change rate of 0.5 ac/h reduces indoor pollutants by 60%. To achieve 90% reduction, the air flow rate of 2 ac/h is required.
Pressurization with Clean Air

**COMMERCIAL BUILDINGS**

- 98% cleaned air in
- FINE FILTER
- Clean: +++
- General: ++
- Dirty: +
- Dirty air out

**HOSPITALS**

- 99.97% cleaned air in
- HEPA
- Cleanest: +++
- Clean: ++
- General: +
- Dirty: -
- Contaminated: --
- HEPA Cleaned air out

98% cleaned air in

Dirty air out
### Filtration and Purification Technologies

<table>
<thead>
<tr>
<th>Filtration technology</th>
<th>Substances to be removed</th>
<th>Possible by products</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RSPM</td>
<td>CO$_2$</td>
</tr>
<tr>
<td>Mechanical filters</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Electrically charged mechanical filter &amp; ionizer</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>HEPA filter</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Electrostatic precipitator</td>
<td>x</td>
<td></td>
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<tr>
<td>Active carbon filter</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Potassium permanganate (KMnO$_4$) filter</td>
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<tr>
<td>Ultraviolet Germicidal Irradiation (UVGI)</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Photocatalytic Oxidation (PCO)</td>
<td>x</td>
<td></td>
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<tr>
<td>Plasma—technology</td>
<td>(x)</td>
<td></td>
</tr>
<tr>
<td>Photo-hydro-ionization (PHI)</td>
<td>(x)</td>
<td></td>
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<tr>
<td>Ionizer</td>
<td>(x)</td>
<td></td>
</tr>
<tr>
<td>Ozoniser</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outdoor air (dilution)</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>
DELHI: Evaporative Cooling in Summer

AC: Designed room air conditions 23 °C / 55%

Off-coil air temperature 13 °C

Summer supply air temperature <26 °C

Delhi monsoon 32 / 28 °C

Delhi summer 42 / 24 °C

Enthalpy difference monsoon 50 kJ/kg

Enthalpy difference summer 35 kJ/kg

Figure 20.6 Psychrometric chart
Do What is Needed to Keep Indoor Air Clean & Healthy

• Ensure the high quality indoor air (low CO₂ and impurities levels) by bringing properly filtered outdoor air into the spaces.
• Prevent the dirty outdoor air entering into the building by positively pressurizing the spaces.
• Prevent dampness & fungi and limit the use of chemicals and VOCs.
• Clean classrooms properly but avoid cleaning products that disinfects the environment (kills necessary bacteria for humans and leaves most harmful fungi and bacteria to grow faster and to emit more toxic gases).
• Use energy efficient equipment and do not oversize them.
• Provide data to the school administration that there is a continuously healthy environment for children to study and personnel to work by installing continuous monitoring devices.
Result: Healthier and Smarter Students

- Even modest changes in room temperature affect student's abilities to perform in tasks requiring mental concentration.

- Children in classrooms with high outdoor air ventilation rates tend to achieve higher scores on standardized tests in math and reading than children in poorly ventilated classrooms.

- High particulate matter concentration prevents the proper development of children’s lungs. At present, nearly 50% of Delhi’s children suffer lung problems due to air pollution (PM$_{2.5}$).

- The presence of fungi and chemicals further increase the risk of asthma and related adverse respiratory health effects as well as allergy and immunity system disorder.