Indoor Air Quality and Health Effects in European Modern Office Buildings

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BACKGROUND

• Workers employed in non-industrial sectors (offices, trade, banking, hospitals, schools, etc.), account for the main part of the labour force in many countries.

• Modern offices are created with the use of new components, materials, equipments and other consumer products, as well as new energy strategies (lightning, heating, cooling and ventilation).

• Growing concern about the pollutants that may be emitted from office equipment (ozone, primary VOCs and particles) and about reactive indoor air chemistry.

• Variety of chemical, physical, biological, ergonomic and psychosocial hazards with a potentially high and diversified impact of work-related health problems.
**On the reduction of health effects from combined exposure to indoor air pollutants in modern offices**

European collaborative project, funded from the European Union FP7 (Agreement 265267) under the Theme ENV.2010.1.2.2-1.

<table>
<thead>
<tr>
<th>Name of organisation</th>
<th>Acronym</th>
<th>Country of origin</th>
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<tbody>
<tr>
<td>1 PANEPISTIMIO DYTIKIS MAKEDONIAS (UNIVERSITY OF WESTERN MACEDONIA)</td>
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<td>2 JRC - JOINT RESEARCH CENTRE- EUROPEAN COMMISSION</td>
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<td>Portugal</td>
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<td>8 KING’S COLLEGE LONDON</td>
<td>TNO</td>
<td>Netherlands</td>
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<td>CSTB</td>
<td>France</td>
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<td>10 CENTRE SCIENTIFIQUE ET TECHNIQUE DU BATIMENT</td>
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<td>11 CONSIGLIO NAZIONALE DELLE RICERCHE</td>
<td>ACCIONA</td>
<td>Spain</td>
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<td>12 ACCIONA INFRAESTRUCTURAS S.A.</td>
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<td>Hungary</td>
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<td>13 EÖTVÖS LORÁND TUDOMÁNYEGYETEM</td>
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<td>15 UNIVERSITA DEGLI STUDI DELL INSUBRIA</td>
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OFFICAIR WP4/WP7: Health effects evaluation in modern office buildings and health risk assessment

• To evaluate the present situation about complaints and symptoms known to be related to IAQ in modern offices across Europe and to assess the correlation of self-reported complaints and symptoms related to IAQ with objective health effects measurements.

• To evaluate the health effects of selected and prioritised IA pollutants, including reaction products, e.g. oxidation product, under different conditions in modern office buildings across Europe, taking into account the role of stress;

• To perform health risk assessment of targeted indoor air pollutants, based on results from this WP (WP7), field campaigns study (WP4), toxicological studies (WP5) and indoor exposure modelling (WP6);

• To evaluate the benefits on health of intervention strategies on IAQ.
On the reduction of health effects from combined exposure to indoor air pollutants in modern offices

Officair

- 8 countries
- 167 buildings
- 7441 office workers
- 2011/2014

Modern Office Buildings (voluntary basis)

Selection criteria:
- to be new or recently retrofitted (<10 years)
- operating in their current form for a min. 1 year prior to the start of the study (preferable 2 years)
- no major renovation / change before the autumn of 2012
Officair Project - WP4/WP7 key strategy

On the reduction of health effects from combined exposure to indoor air pollutants in modern offices (EU FP7 Env 2010).

General survey: 167 buildings – ~7500 workers – Questionnaire + building checklist

DETAILED study: 37 buildings – ~1400 workers – «classical» measurements + detailed checklist

2 SEASONS

INTERVENTION study: 9 buildings – ~250 workers – Innovative measurement and strategy

BEFORE & AFTER AN INTER.

7440 workers investigated in eight European countries, representing all the European climatic regions

HEALTH RISK ASSESSMENT

HEALTH RISK MANAGEMENT
Self-reported health and comfort in ‘modern’ office buildings: first results from the European OFFICAIR study

Abstract In the European research project OFFICAIR, a procedure was developed to determine associations between characteristics of European offices and health and comfort of office workers, through a checklist and a self-administered questionnaire including environmental, physiological, psychological, and social aspects. This procedure was applied in 167 office buildings in eight European countries (Austria, Spain, Italy, Greece, France, Portugal, UK, and Switzerland).
ON THE REDUCTION OF HEALTH EFFECTS FROM COMBINED EXPOSURE TO INDOOR AIR POLLUTANTS IN MODERN OFFICES

Health and comfort in ‘modern’ office buildings

N. Buildings 156; N. workers 7192
ON THE REDUCTION OF HEALTH EFFECTS FROM COMBINED EXPOSURE TO INDOOR AIR POLLUTANTS IN MODERN OFFICES

N. Buildings 156; N. workers 7192

Fig. 4 Prevalence of building-related health symptoms in the OFFICAIR study
Association between Environmental perception and Symptoms

1. Environmental perception and Symptoms
   - Age
   - Female gender
   - To be married

2. Environmental perception → Symptoms
   - Air quality, Air too dry → Irritative symptoms / respiratory symptoms
   - Noise → Cardiovascular symptoms
Self-reported health and comfort in ‘modern’ office buildings: first results from the European OFFICAIR study

Abstract In the European research project OFFICAIR, a procedure was developed to determine associations between characteristics of European offices and health and comfort of office workers, through a checklist and a self-administered questionnaire including environmental, physiological, psychological, and social aspects. This procedure was applied in 167 office buildings in 14 European countries between 2000 and 2002. The objectives were to determine the health and comfort of office workers and their associations with building characteristics. The study found that the number of occupants, lack of operable windows, presence of carpet, and cleaning activities were significantly associated with negative environmental perceptions. Mold growth, acoustical solutions, and cleaning activities were associated with symptoms.

Building characteristics associated with negative environmental perceptions:
number of occupants, lack of operable windows, presence of carpet, and cleaning activities

Building characteristics associated with symptoms:
mold growth, acoustical solutions, and cleaning activities
Office characteristics and dry eye complaints in European workers—The OFFICAIR study

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h University of Western Macedonia, Siavhera and Bakola Street, 50100 Kozani, Greece
Conclusions

The high prevalence of self-reported dry eye complaints in offices may be explained by:

- **work-related factors** (e.g. ‘Visual Display Unit’ use),

- **office building characteristics** which may affect exposure to environmental conditions:
  - nearby outdoor pollution sources,
  - absence of operable windows
  - certain types of wall coverings,
  - portable humidifiers,
  - locations of printers/copy machines
  - the frequency of surface cleaning activities.

De Kluizenaar et al., 2016
Psychosocial work environment and building related symptoms

The OFFICAIR study

Céline RODA
Philomena M. Bluyssen, Corinne Mandin, Serena Fossati, Paolo Carrer, Yvonne de Kluizenaar, Victor G. Mihucz, Eduardo de Oliveira Fernandes, and John Bartzis
Effort-reward imbalance model \cite{Siegrist1996, Siegrist2004}

**Extrinsic components**
- Effort
  - demands / obligations
- Reward
  - labour income
  - career mobility / job security
  - esteem, respect

**Intrinsic component**
- motivation ('overcommitment')
Psychosocial work environment

ER-ratio > 1

High efforts / Low rewards (tertiles)

Courtesy of Celine Roda et al. Healthy Buildings Conference 2015
Association between work-related stress and building related symptoms

**Eye irritation**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Adjusted OR [95% CI]</th>
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<tbody>
<tr>
<td>High efforts / High rewards (vs. LE/HR)</td>
<td></td>
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<tr>
<td>Low efforts / Low rewards (vs. LE/HR)</td>
<td></td>
</tr>
<tr>
<td>High efforts / Low rewards (vs. LE/HR)</td>
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<tr>
<td>High overcommitment (vs. low)</td>
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**Upper respiratory symptoms**

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<th>Adjusted OR [95% CI]</th>
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<tr>
<td>High overcommitment (vs. low)</td>
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</table>

**General symptoms**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Adjusted OR [95% CI]</th>
</tr>
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<tbody>
<tr>
<td>High efforts / High rewards (vs. LE/HR)</td>
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<tr>
<td>Low efforts / Low rewards (vs. LE/HR)</td>
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<td></td>
</tr>
<tr>
<td>High overcommitment (vs. low)</td>
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**Skin symptoms**

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<tr>
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<th>Adjusted OR [95% CI]</th>
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<tbody>
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<td>High efforts / Low rewards (vs. LE/HR)</td>
<td></td>
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<tr>
<td>High overcommitment (vs. low)</td>
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Adjusted for sex, age, educational level, job, tobacco smoke status, current alcohol consumption and negative affectivity

Courtesy of Celine Roda et al. *Healthy Buildings Conference 2015*
Conclusions

- **Association between work-related stress and health** in a large European cross-sectional study
  - office workers with high efforts and low rewards: ↑ risk of BRSs

- **Complex effects** of psychosocial factors on BRSs
  - impact on workers’ perceptions of health psychologically or susceptibility to environmental exposures physically increased

- **Multi-disciplinary approach** needed
  - psychosocial environment should be considered in order to provide a healthy work environment

Celine Roda et al. *Healthy Buildings Conference 2015*
INTERVENTION STUDY

- 1-2 BUILDING PER COUNTRY:  
  - BEFORE INTERVENTION (January/March 2013)  
  - AFTER INTERVENTION (March/May 2013)

- INTERVENTION STRATEGIES RELATED TO IAQ
  - floor cleaning products with low terpenes contents
  - cleaning procedures (NL)

- WP4: ENVIRONMENTAL MONITORING
  Detailed and innovative IAQ investigation

- WP7: HEALTH EFFECTS
  Basic and Plus protocol to investigate the sensory irritation, the inflammatory and oxidative effects (both local, i.e. in the airways, and systemic), and the endothelial and autonomic dysfunction due to exposure to targeted indoor air pollutants (including reaction products).
**INTERVENTION study – Basic protocol**

Same protocol as in the detailed study + biological samples easy to perform

In I, NL, GR, PT, HU, FR

20-30 workers/building x 2 times (morning-afternoon) x 2 survey x 1-2 buildings

9 Buildings – 259 Workers - Total measurements: 560 – 1640

<table>
<thead>
<tr>
<th>Outcome</th>
<th>To investigate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questionnaire and tests</td>
<td>Environmental perception, symptoms, performance, eyes health</td>
</tr>
<tr>
<td><strong>Lung function</strong>: Peak of Expiratory Flow (PEF) and forced expiratory volume in 1 second (FEV$_1$)</td>
<td>Lung function</td>
</tr>
<tr>
<td>Arterial blood pressure</td>
<td>Vascular function</td>
</tr>
<tr>
<td>Response of <strong>blood pressure</strong> to orthostatic challenge.</td>
<td>Autonomic dysfunction</td>
</tr>
<tr>
<td><strong>Urinary 8-isoprostane</strong></td>
<td>Systemic oxidative stress</td>
</tr>
<tr>
<td><strong>Salivary cortisol</strong></td>
<td>Work-related stress</td>
</tr>
</tbody>
</table>
**INTERVENTION Study – Plus protocol**

Comprehensive protocol in two buildings only in Italy
A total of 50-100 workers x 2 times (morning-afternoon) x 2 survey
Total measurements: 200 – 400

<table>
<thead>
<tr>
<th>Outcome</th>
<th>To investigate</th>
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<tbody>
<tr>
<td>In <strong>exhaled breath condensate</strong> (EBC):</td>
<td>Local lung inflammation and oxidative stress</td>
</tr>
<tr>
<td>-8-isoprostane</td>
<td></td>
</tr>
<tr>
<td>-Cytokines (IL-8, IL-1beta)</td>
<td></td>
</tr>
<tr>
<td>-pH</td>
<td></td>
</tr>
<tr>
<td><strong>FeNO in exhaled air</strong></td>
<td>Local lung inflammation</td>
</tr>
<tr>
<td><strong>Peripheral arterial tonometry (PAT)</strong></td>
<td>Microvascular function</td>
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<tr>
<td><strong>Heart rate variability (HRV)</strong></td>
<td>Autonomic dysfunction</td>
</tr>
</tbody>
</table>
Intervention Area - IAQ related symptoms
(last week)

- Dry eyes
- Watering or itchy eyes
- Burning or irritated nose
- Blocked or stuffy nose
- Runny nose
- Sneezing
- Dry/irritated throat
- Flu-like symptoms
- Cough
- Wheezing
- Tachycardia
- Phlegm/mucus
- Chest...
- Bradycardia
- Irregular heart beats
- Rush or irritated skin
- Headache
- Lethargy, unusual...

PRE (N=85)
POST (N=85)
### Health Risk Assessment

#### Table 6: Average and maximum measured indoor air concentrations (µg/m³) (2-h mean) reported in the ‘intervention study’ and comparison with acute limits of exposure – intervention room: before and after the intervention strategy.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Limit of exposure (µg/m³)</th>
<th>Conc. (µg/m³) Before intervention</th>
<th>Limit of exposure (%)</th>
<th>Conc. (µg/m³) After intervention</th>
<th>Limit of exposure (%)</th>
<th>Conc. (µg/m³) Before intervention</th>
<th>Limit of exposure (%)</th>
<th>Conc. (µg/m³) After intervention</th>
<th>Limit of exposure (%)</th>
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<tr>
<td>formaldehyde¹</td>
<td>100²</td>
<td>14</td>
<td>14</td>
<td>7</td>
<td>7</td>
<td>37</td>
<td>37</td>
<td>8</td>
<td>8</td>
</tr>
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<td>acrolein²</td>
<td>21</td>
<td>2</td>
<td>9</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>19</td>
<td>1</td>
<td>5</td>
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<tr>
<td>d-limonene³</td>
<td>90000³</td>
<td>15</td>
<td>&lt;1</td>
<td>8</td>
<td>&lt;1</td>
<td>166</td>
<td>&lt;1</td>
<td>92</td>
<td>&lt;1</td>
</tr>
<tr>
<td>α-pinene⁴</td>
<td>45000³</td>
<td>1</td>
<td>&lt;1</td>
<td>3</td>
<td>&lt;1</td>
<td>166</td>
<td>&lt;1</td>
<td>92</td>
<td>&lt;1</td>
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<tr>
<td>6-MHO⁵</td>
<td>1550³</td>
<td>2.5</td>
<td>&lt;1</td>
<td>3</td>
<td>&lt;1</td>
<td>12</td>
<td>&lt;1</td>
<td>14</td>
<td>&lt;1</td>
</tr>
<tr>
<td>4-OPA⁶</td>
<td>246</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>3</td>
<td>1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

¹ max concentration reported for building code PT17
² max concentration reported for building code PT17
³ max concentration reported for building code PT13
⁴ max concentration reported for building code NL02
⁵ max concentration reported for building code PT13
⁶ max concentration reported for building code IT03
⁷ should not be exceeded at any 30-min interval during the day (WHO 2010 guideline value)

**Note:** for HRA, intervention room measurements before intervention strategy not available from FR for d-limonene, α-pinene, 6-MHO, 4-OPA.
- In Intervention area decreased for dry eyes
- Significant decrease in post intervention area in the Exhaled breath condensate (EBC) acidity → low inflammation?
- Benefits on health parameters due to intervention strategies and the role of work-related stress are ongoing.
Indoor Air Quality and Health Effects in European Modern Office Buildings

- Frequent negative environmental perceptions (>30%) for air too dry, air stuffy, air smelly; noise from inside building in modern office buildings
- Frequent eye symptoms (>20%)
- Environmental perceptions associated with mold growth, acoustical solutions, cleaning activities
- Symptoms associated with number of occupants, lack of operable windows, presence of carpet, and cleaning activities
- Complex effects of psychosocial factors on BRSs
Officair project: expected developments

- Role of cleaning activities on IAQ need to be investigated (Intervention study)
- Role of noise in association with IAQ on cardiovascular symptoms need to be investigated
- Office workers with high efforts and low rewards have an higher risk of building related symptoms

*Complex effects of psychosocial factors on BRSs:*

⇒ *impact on workers’ perceptions of health or increased susceptibility to environmental exposures*
**Officair** project: expected developments

- **Improved knowledge and tools** to evaluate in office buildings indoor air, total exposure and related health impacts
- **Improved risk assessment data** for the creation of good practices and target indicators for design, construction, maintenance and management of modern office buildings
- **Recommendations and prioritization** of IAQ policies related to office buildings in the context of the ongoing Building Energy Efficiency regulations.
• Opportunity of connections with other EU projects:
  – **SINPHONIE**: IAQ in schools
  – **EU-LCI**: Harmonisation of the health based evaluation of emissions from building products in the EU using the LCI-concept
  – **EPHECT**: Emissions, exposure patterns and health effects of consumer products in the EU
  – **HEALTHVENT**: Health-based ventilation guidelines
Thanks for your attention

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