Prospective monitoring of Exposure and Lung Function among Cement Production Workers
A EUROPEAN research project involving CEIS and the Occupational health services at Turkish cement plants

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National Institute of Occupational Health, Oslo, Norway
Presentation at the CEIS 50th Anniversary Symposium 10 Oct 2014 with the warmest congratulations

Monitoring of Exposure and Lung Function among Cement Workers
Funding was provided by CEMBUREAU
with the National coordinators and researchers

Planning the data collection, Ankara 2006

Turkey provided 59 % of all data in the study
Meeting at the end of the data collection, Istanbul 2012.

Prospective monitoring of exposure and lung function among cement workers

Two elements of the study

• Exposure assessment
  – Personal air samples
  – Thoracic aerosol mass
  – Group-based sampling by plant * job type

• Lung function (spirometry)
  – Dynamic lung volumes
  – Two-year interval between spirometries
  – Exposure allocated by job type x plant
Data collection for the project

• National coordinators
  – Knowledge of the production methods
  – Manuals and questionnaires
  – Organizing the data collection, shipping of data and equipment

• Occupational health services
  – Collecting samples of dust from the work atmosphere using personal sampling
  – Perform lung function tests
  – Questionnaire fill-out

Exposure sources

- Raw materials
- Crushing and milling
- Clinker milling
- Clinker transport
- Car tires
- Household waste
- Coal
- Special waste
**Job types in cement plants**

- Production
- Cleaning
- Maintenance
- Foreman
- Laboratory
- Other
- Administration/management

**Exposure and lung function measurements**

  - Filters from cyclones
  - Questionnaires
    - 6100 samples representing 162 combinations job type x plant
    - Estimated mean exposure from mixed effect models -> JEM using
      - Geometric mean; by job type, plant, year, season
      - Variance calculated by plant
Exposure sampling

Filters from the exposure sampling
Results, Exposure

- Production, cleaning, and maintenance work were the job types with highest exposure to thoracic aerosol in cement production plants.
- Plant had an even larger effect on exposure levels than job type.
- The number of employees important factor explaining differences between plants.
- Exposure reached levels where the risk of lung function loss may be increased.
- No significant differences in exposure between sampling campaigns (years) were observed

Nøtø et al, Exposure to Thoracic Aerosol in a Prospective Lung Function Study of Cement Production Workers, accepted for publication Ann Occup Hyg, 2014

Lung function measurements - spirometry

  - FEV₁ (forced expiratory volume in one second)
    - Questionnaires
  - 4990 persons
  - 11 000 spirometry tests in total
  - 2400 persons performed 3 tests
Spirometry performed by occupational health service teams
Spirometry performed by occupational health service teams
Spirometry performed by occupational health service teams

A total of 11,000 spirometries were performed in all 8 countries........
We most heartily provide our thanks to the participating plants!

And we would like to underscore the importance of the OSH in the sustainability in the workplace.
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A few results, lung function.
• Elevated odds ratios for symptoms and airflow limitation (range 1.2–2.6 in the highest quartile), but not for chronic bronchitis, were found in the higher quartiles of exposure compared with the lowest quartile.
• Forced expiratory volume in 1 s (FEV\textsubscript{1}) showed an exposure–response relationship with a 270-mL deficit of FEV\textsubscript{1} (95% CI 190–300 mL) in the highest compared with the lowest exposure level.
• The results support the hypothesis that exposure to dust in cement production may lead to respiratory symptoms and airway obstruction.

• Nordby et al, ERJ 2011
• From an exposure level of (1.86 – 2.78 mg/m³) and higher, we found increased loss of dynamic lung volume.
• The loss of dynamic lung volume in the administration compares to the loss in the lowest quintile of exposure (below 0.72 mg/m³).
• Dose-response in most outcome measures except for FVC suggests that the observed effect is causal.

Key role for OSH providing backbone for healthy workplaces.

• CEIS and the participating Turkish cement production plants with their occupational health service teams contributed substantially to this exposure-response study.
• The results indicate a need to reduce exposure by engineering and use of protective equipment among those exposed to the higher levels of dust encountered.
• The suggestion to offer spirometry to the employees as a health surveillance tool in the cement production industry is supported.
Acknowledgements & collaborators
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  • Management and workers in the Turkish plants of:
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    – BUYUKCEKMECE
    – NUH
    – BOLU
    – ANKARA (LIMAK, FORMERLY SET)
    – BASTAS
    – BATICIM
    – CIMENTAS
    – DENIZLI
• Management and workers in the participating plants in seven other countries

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Oslo University Hospital
  • Johny Kongerud, Anne Kristin Fell

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  • Hilde Notø, Marit Skogstad, Wijnand Eduard, Yngvar Thomassen, Helge Kjuus, Øivind Skare, Karl-Christian Nordby
Most photos: Thanks to Hilde Notø

The End
Extra slides, evaluation of exposure levels

**Thoracic aerosol level (mg/m³)**
- Ex 1 = 0.13 – 0.72
- Ex 2 = 0.73 – 1.38
- Ex 3 = 1.39 – 1.85
- Ex 4 = 1.86 – 2.78
- Ex 5 = 2.79 – 10.3

Adjustments were made for:
- allergy
- smoking (pack-years)
- previous exposure (gas/dust) at baseline, and for
- smoking during follow-up (py)

Administration and self-reported doctor-diagnosed asthma excluded

ESCS=European prediction values

**Change per year in FEV₁, % of predicted (ESCS), adjusted RD, n=2597, 21 plants**

THIS IS ONLY TO GIVE A QUICK VIEW OF LONGITUDINAL RESULTS

-1,400
-1,200
-1,000
-800
-600
-400
-200
0
200
400
600
800
1,000
1,200
1,400

Δ FEV₁ % predicted

Estimate
95% Confidence interval
Comparison of the measurements from the Thoracic cyclone and the Total dust sampler

\[ R^2 = 0.889 \]

\[ mg/m^3 \text{ TK} = -0.009 + 0.385 \times mg/m^3 \text{ Tot} \]

AM estimated and AM observed thoracic aerosol levels for all plants and years by job type

- Production (P)
- Cleaning
- Maintenance
- Foreman
- Adm
- Laboratory
- Other
- Several
Estimated and observed AM for each plant with the mean of the 3 sampling periods for each job type.
Production AM estimated = $-0.091 + AM_{observed}$

$R^2 = 0.83$

Lung function: Volume-time measurements

Forced expiratory volume in 1 sec., FEV1
Prospective study on lung function
\( \Delta \text{FEV}_1 \text{/time} \)

Age dependent annual fall in FEV, 0-60ml/year

Study outline – 2007-2011

5000 participants – 8 countries

Health q. Year 1,3,5
Spirometry Year 1,3,5
Exposure q Last 2 years Year 1,3,5
Exposure sampling Year 1,3,5
Exposure q Tasks, day of each sampling

Lung function decline
Predicted exposure
Job Exposure Matrix JEM

Exposure-outcome associations
Results, cross-sectional analysis of airway symptoms and COPD

Logistic regression OR (CI 95%), adjusted for gender, age, and smoking. Employees reporting a doctor-diagnosed asthma were excluded from analysis (n=116)
COPD = Chronic Obstructive Pulmonary Disease (FEV\(_1\)/FVC < LLN5)

<table>
<thead>
<tr>
<th>Exposure, mg/m(^3)</th>
<th>Cough + wheeze + dyspnea N=3495</th>
<th>Chronic bronchitis N=3495</th>
<th>COPD 2632</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low &lt;0.49</td>
<td>1=reference</td>
<td>1=reference</td>
<td>1=reference</td>
</tr>
<tr>
<td>Level 2 0.49-1.08</td>
<td>2.4 (1.3-4.4)</td>
<td>1.0 (0.6-1.6)</td>
<td>1.4 (0.7-3.0)</td>
</tr>
<tr>
<td>Level 3 1.09-1.73</td>
<td>2.2 (1.2-4.0)</td>
<td>0.6 (0.3-1.0)</td>
<td>2.2 (1.1-4.4)</td>
</tr>
<tr>
<td>High &gt;1.74</td>
<td>2.3 (1.3-4.4)</td>
<td>0.5 (0.2-0.8)</td>
<td>1.8 (0.9-3.8)</td>
</tr>
</tbody>
</table>

Employees reporting job type = administration (n=629) were excluded from analysis (no representative exposure measurements for this group)

Nordby et al., ERJ 2011

Results, cross-sectional analysis of lung function

Linear regression, RD (CI 95%), adjusted for gender, age, allergy, smoking, previous exposure.
Confidence intervals overlapping unity = ns

<table>
<thead>
<tr>
<th>Exposure, mg/m(^3)</th>
<th>FVC mL 2696</th>
<th>FEV(_1) mL 3244</th>
<th>FEV(_1)/ FVC % 2599</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low &lt;0.49</td>
<td>0=reference</td>
<td>0=reference</td>
<td>0=reference</td>
</tr>
<tr>
<td>Level 2 0.49-1.08</td>
<td>-180 (-270; -99)</td>
<td>-140 (-200; -79)</td>
<td>-0.4 (-1.0; +0.3)</td>
</tr>
<tr>
<td>Level 3 1.09-1.73</td>
<td>-210 (-290; -120)</td>
<td>-210 (-280; -150)</td>
<td>-0.8 (-1.5; -0.2)</td>
</tr>
<tr>
<td>High &gt;1.74</td>
<td>-300 (-390; -220)</td>
<td>-270 (-330; -200)</td>
<td>-0.8 (-1.4; -0.2)</td>
</tr>
</tbody>
</table>

Employees reporting job type = administration (n=629) were excluded as representative exposure measurements were not performed in this group.
Participants with doctor-diagnosed asthma were excluded

Nordby et al., ERJ 2011
Particle size distribution

<table>
<thead>
<tr>
<th></th>
<th>% of total dust</th>
<th>% of Inhalable aerosol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thoracic</td>
<td>Respirable</td>
</tr>
<tr>
<td>Mean</td>
<td>45,1</td>
<td>24,3</td>
</tr>
<tr>
<td>Median</td>
<td>40,7</td>
<td>19,2</td>
</tr>
</tbody>
</table>

The correlation between the Thoracic cyclone and the Total dust sampler

\[
\text{R}^2 = 0.889 \\
\text{mg/m}^3 \text{TK} = -0.009 + 0.385 \times \text{mg/m}^3 \text{Tot}
\]

Variable | Obs | Mean | Std. | Min | Max |
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>mg/m3TK</td>
<td>140</td>
<td>1.3</td>
<td>3.0</td>
<td>0.02</td>
<td>18.2</td>
</tr>
<tr>
<td>mg/m3Tot</td>
<td>89</td>
<td>4.8</td>
<td>9.0</td>
<td>0.003</td>
<td>64.3</td>
</tr>
</tbody>
</table>
ΔFEV₁/h² per year by plant and exposure intensity

Thoracic aerosol level (mg/m³)
- Ex 1: 0.13 – 0.72
- Ex 2: 0.73 – 1.38
- Ex 3: 1.39 – 1.85
- Ex 4: 1.86 – 2.78
- Ex 5: 2.79 – 10.3

Adjustments were made for:
- plant
- sex
- age
- allergy
- smoking (pack-years)
- previous exposure (gas/dust) at baseline, and for
- smoking during follow-up (py)

Administration and self-reported doctor-diagnosed asthma excluded

Units used in the analyses

<table>
<thead>
<tr>
<th>Measure</th>
<th>Unit</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume change per height squared</td>
<td>ml/m²</td>
<td>Baseline: -18; +134</td>
</tr>
<tr>
<td>Observational time between occasions</td>
<td>Year (yr)</td>
<td>0 (in 2007)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.96 - 2.9 (2007-2009, 2009-2011)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.69 - 4.68 (from 2007-2011)</td>
</tr>
<tr>
<td>Gender, Allergy, Asthma, Previous expo to dust/gas</td>
<td>Indicator</td>
<td>0; 1 (for gender: male=1)</td>
</tr>
<tr>
<td>Pack years during Obs time</td>
<td>Number</td>
<td>0 - 10.5 (in a maximum of 4.7yr)</td>
</tr>
<tr>
<td>Age</td>
<td>Years</td>
<td>17-81, calculated to age in 2007</td>
</tr>
<tr>
<td>Exposure quintiles, estimated arithmetic mean from JEM</td>
<td>mg/m³ thoracic dust</td>
<td>1: 0.13-0.61</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2: 0.62-1.57</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3: 1.58-2.27</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4: 2.28-5.40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5: 5.41-14.1</td>
</tr>
<tr>
<td>Effect measure</td>
<td>ml/m² (yr * mg/m³)</td>
<td>-6; -19 (in main analysis)</td>
</tr>
</tbody>
</table>
Hypothesis

- Inhalant exposure to the bronchial tree (represented by the thoracic aerosol) may lead to obstructive lung changes, leading to loss of lung volumes in excess of the expected “normal” age-dependent loss.
ACGIH Notice 2006: Suggestion for a new OEL

The American Conference on Governmental Industrial Hygienists’ (ACGIH) Notice of Intended Change for 2006 suggest a new OEL for Portland cement:

- 1 mg/m³ TWA (Time weighted average, inhalable particulate mass)
- 5 mg/m³ STEL (Short-term exposure limit)
- A2: Suspected Human Carcinogen

The present Norwegian OEL for cement dust (total dust): 10mg/m³

Previous studies on lung effects in cement workers
Previous studies on lung effects in cement workers

Exp/response

Portland cement – risk of respiratory disease

• “Overall, the pattern of evidence clearly indicates that occupational exposure to cement dust has produced deficits in respiratory function.”

• “However, the evidence available at the present time is insufficient to establish with any confidence the dose-response relationship for these effects.”

• “The effects of long-term exposure remain poorly studied, particularly because there are no longitudinal prospective studies in workers exposed to cement.”