Modelling of exposure to inhalable and respirable welding fumes at German workplaces

Benjamin Kendzia\textsuperscript{a}, Dorothea Koppisch\textsuperscript{b}, Rainer Van Gelder\textsuperscript{b}, Wolfgang Zschiesche\textsuperscript{a}, Thomas Behrens\textsuperscript{a}, Thomas Brüning\textsuperscript{a}, Beate Pesch\textsuperscript{a}

\textsuperscript{a} Institute for Prevention and Occupational Medicine of the German Social Accident Insurance, Institute of the Ruhr University Bochum (IPA), Germany
\textsuperscript{b} Institute for Occupational Safety and Health of the German Social Accident Insurance (IFA), Germany

9th International Conference on the Science of Exposure Assessment
Manchester, UK, 24-26 September 2018
Background & Objectives

• Worldwide ~120 million workers are exposed to welding fumes

• The International Agency for Research on Cancer classified welding fumes as carcinogenic to humans (2017)

• The increased lung cancer risk of welders is frequently based on job title or task. Few studies estimate the level of exposure to welding fumes.

• Aim: **Quantitative estimation of average concentrations of inhalable and respirable welding fumes** using the German exposure database MEGA (in order to estimate lung cancer risks in two case-control studies)
Definition of the particle-size fraction

- **Inhalable fraction**
  - Fraction of total airborne particles that enters the body through the nose and/or mouth
  - Corresponding to particles with aerodynamic diameter \( d_{ae} \leq 100 \, \mu m \)

- **Respirable fraction**
  - Subfraction of the inhaled particles \( d_{ae} < 10 \, \mu m \)
  - Penetrates into the alveolar region of the lung

Source: Lidén and Harper, 2007
Sampling of inhalable and respirable welding fumes

• Sampling of welding fumes at German workplaces (1983-2016)
• Samplers were positioned on the welder without side preference and usually outside of the hood/helmet in the breathing zone
• Use of different samplers (GSP 3.5, FSP 10, PGP-EA,…)
• Welding fume concentrations were compiled with information on the measurement and workplace conditions
• Mass concentrations were determined gravimetrically by weighing at Institute for Occupational Safety and Health according to ISO 15767

Statistical analysis of welding fume concentrations: 15,473 for inhalable and 9,161 for respirable fumes
Assessment of welding settings

• All welding workplaces were documented with a detailed description of the welding tasks and occupational settings

→ Classification of welders by the predominantly applied welding process
Gas metal arc welding (MAG, MIG), tungsten inert gas welding (TIG), shielded metal arc welding (SMAW), FCAW, laser, autogenous, submerged arc welding etc.

→ For major processes: Definition of consumable welding material
Mild steel: Chromium and nickel content <10%
Stainless steel: Chromium or/and nickel content ≥10%
Statistical analysis for both particle-size fractions

- **Multiple imputation** of concentrations below limit of detection (LOD) according to the distribution of concentrations >LOD
- Generation of 10 data sets with imputed concentrations (random)
- **Mixed-effects model**
  \[
  \log(\text{welding fume concentration}) = \beta_1 \times \text{Welding process} \\
  + \beta_2 \times \text{Consumable material} \\
  + \beta_3 \times \text{Year (median-centered)} \\
  + \beta_4 \times \log(\text{sampling duration})
  \]
- Combining of regression coefficients $\beta_i$ from all 10 runs of this model
- **Model-based geometric means (GMs)** of exposure were centred at the median calendar year and sampling duration
## Results

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Inhalable fraction</th>
<th>Respirable fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most frequent welding process</td>
<td>MAG (n=7,160)</td>
<td>MAG (n=4,854)</td>
</tr>
<tr>
<td>Most frequent consumable material</td>
<td>Mild steel (n=5,307)</td>
<td>Mild steel (n=3,839)</td>
</tr>
<tr>
<td>Most frequent sampler type</td>
<td>GSP 3.5 (n=11,159)</td>
<td>FSP 10 (n=4,417)</td>
</tr>
<tr>
<td>N&lt;LOD [%]</td>
<td>23</td>
<td>26</td>
</tr>
<tr>
<td>Median duration of sampling duration [h]</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Trend by sampling duration [% per hour]</td>
<td>-12.8 (p&lt;0.0001)</td>
<td>-12.5 (p&lt;0.0001)</td>
</tr>
<tr>
<td>Median calendar year</td>
<td>2003</td>
<td>2009</td>
</tr>
<tr>
<td>Time trend [% per year]</td>
<td>-3 (p=0.0002)</td>
<td>-4 (p&lt;0.0001)</td>
</tr>
<tr>
<td>Adjusted R^2 (95% CI)</td>
<td>0.34 (0.33-0.35)</td>
<td>0.43 (0.42-0.44)</td>
</tr>
</tbody>
</table>
## Model-based estimates of average welding fume concentrations

<table>
<thead>
<tr>
<th>Welding process</th>
<th>Inhalable fraction [mg/m$^3$]</th>
<th>Respirable fraction [mg/m$^3$]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>GM*</td>
</tr>
<tr>
<td>Metal active gas welding</td>
<td>7,160</td>
<td>3.3</td>
</tr>
<tr>
<td>Metal inert gas welding</td>
<td>1,161</td>
<td>3.0</td>
</tr>
<tr>
<td>Flux-cored arc welding</td>
<td>258</td>
<td>4.7</td>
</tr>
<tr>
<td>Tungsten inert gas welding</td>
<td>1,853</td>
<td>0.7</td>
</tr>
<tr>
<td>Shielded metal arc welding</td>
<td>1,743</td>
<td>2.3</td>
</tr>
<tr>
<td>Autogenous welding</td>
<td>53</td>
<td>0.9</td>
</tr>
<tr>
<td>Laser welding</td>
<td>287</td>
<td>0.3</td>
</tr>
<tr>
<td>Submerged arc welding</td>
<td>97</td>
<td>1.9</td>
</tr>
</tbody>
</table>

*GMs standardized to the median year and sampling time.
Average inhalable exposure by major process and content

GMs standardized to the median year and sampling duration
Average respirable exposure by major process and content

GMs standardized to the median year and sampling duration
Strengths

- Large number of personal measurements in two particle-size fractions
- Detailed data about sampling and welding task (process and material)

Limitations

- Use of different samplers across time
- Lack of additional information on welding in confined spaces, position of samplers, or efficiency of local exhaust ventilation
- Median duration of sampling was 2 hours
Conclusions

• Exposure was strongly influenced by welding technique

• Highest GMs in both particle-size fractions: Flux-cored arc welding

• Job title “welder” is not sufficient to capture the wide range of exposure

• In order to assess exposure to welding fumes in community-based studies, supplemental information on welding settings should be collected

• Next step: Linking exposure to welding fumes with occupational histories of cases and controls to calculate cumulative exposure and to estimate the lung cancer risk