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

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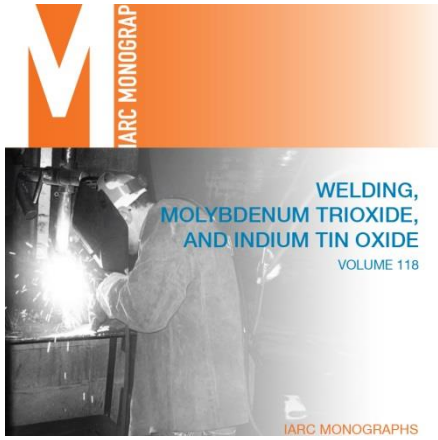
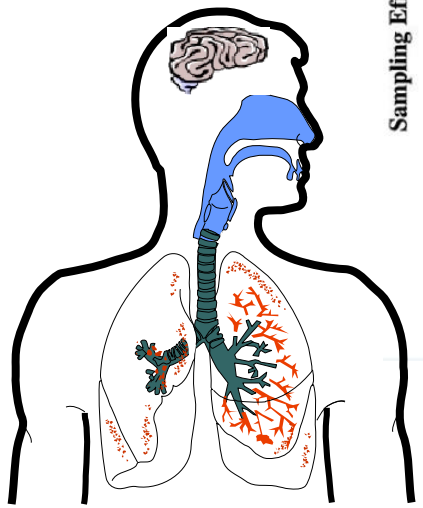
# Background & Objectives

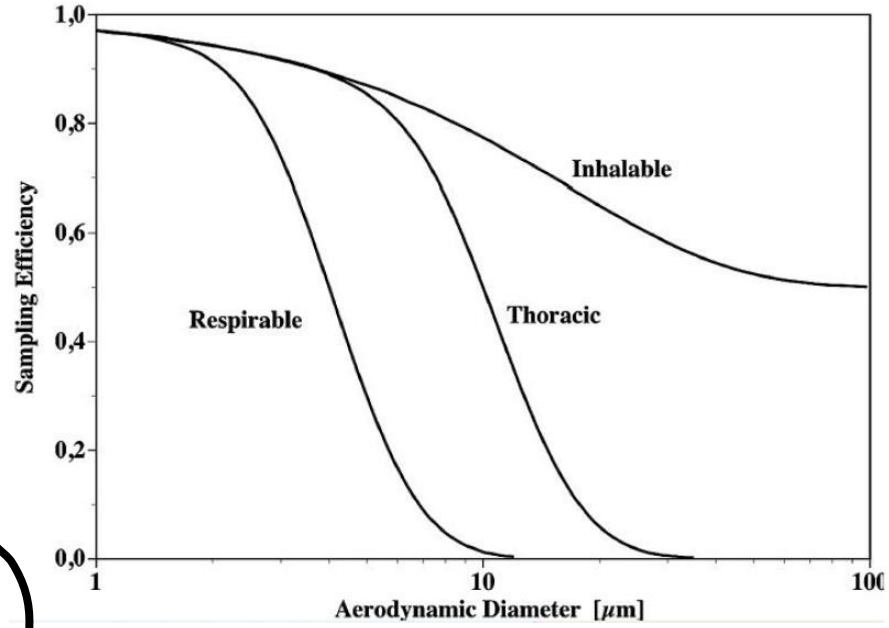



- Worldwide ~120 million workers are exposed to welding fumes
- The International Agency for Research on Cancer classified welding fumes as carcinogenic to humans (2017)
- The increased lung cancer risk of welders is frequently based on job title or task. Few studies estimate the level of exposure to 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 ($d_{ae}$) ≤100 µm
- **Respirable fraction**
  - Subfraction of the inhaled particles ($d_{ae}$<10 µm)
  - 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**

$$\begin{aligned}\log(\text{welding fume concentration}) = {} & \beta_1 \times \textit{Welding process} \\ & + \beta_2 \times \textit{Consumable material} \\ & + \beta_3 \times \textit{Year (median-centered)} \\ & + \beta_4 \times \textit{log(sampling duration)}\end{aligned}$$

- 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

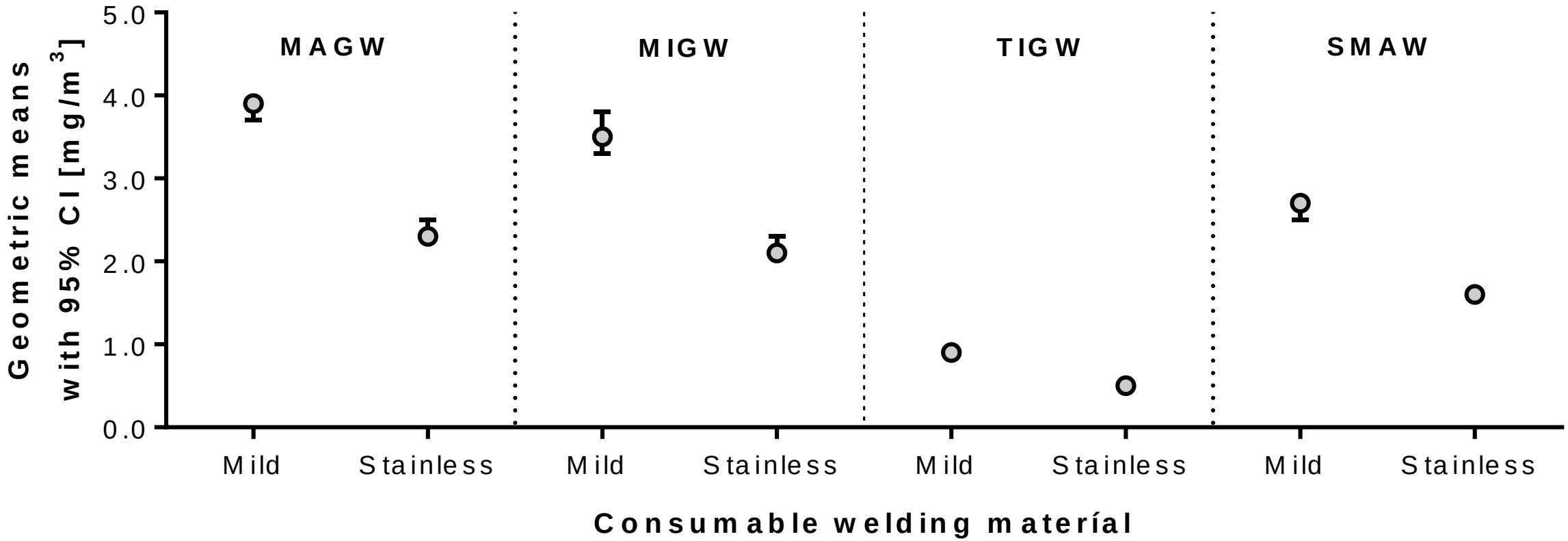
| Characteristics | Inhalable fraction | Respirable fraction |
|---|---|---|
| Most frequent welding process | MAG (n=7,160) | MAG (n=4,854) |
| Most frequent consumable material | Mild steel (n=5,307) | Mild steel (n=3,839) |
| Most frequent sampler type | GSP 3.5 (n=11,159) | FSP 10 (n=4,417) |
| N<LOD [%] | 23 | 26 |
| Median duration of sampling duration [h] | 2 | 2 |
| Trend by sampling duration [% per hour] | -12.8 (p<0.0001) | -12.5 (p<0.0001) |
| Median calender year | 2003 | 2009 |
| Time trend [% per year] | -3 (p=0.0002) | -4 (p<0.0001) |
| Adjusted $R^2$ (95% CI) | 0.34 (0.33-0.35) | 0.43 (0.42-0.44) |

# Model-based estimates of average welding fume concentrations

| Welding process | Inhalable fraction [mg/m³] | | | Respirable fraction [mg/m³] | | |
|---|---|---|---|---|---|---|
| | N | GM* | 95% CI | N | GM* | 95% CI |
| Metal active gas welding | 7,160 | **3.3** | 3.2-3.4 | 4,854 | **1.5** | 1.4-1.5 |
| Metal inert gas welding | 1,161 | **3.0** | 2.8-3.2 | 543 | **1.8** | 1.6-2.0 |
| Flux-cored arc welding | 258 | **4.7** | 4.0-5.4 | 149 | **2.2** | 1.8-2.7 |
| Tungsten inert gas welding | 1,853 | **0.7** | 0.7-0.8 | 921 | **0.3** | 0.3-0.3 |
| Shielded metal arc welding | 1,743 | **2.3** | 2.1-2.4 | 521 | **0.9** | 0.9-1.1 |
| Autogenous welding | 53 | **0.9** | 0.6-1.2 | 32 | **0.3** | 0.2-0.5 |
| Laser welding | 287 | **0.3** | 0.2-0.3 | 225 | **0.2** | 0.1-0.2 |
| Submerged arc welding | 97 | **1.9** | 1.5-2.4 | 72 | **0.6** | 0.5-0.8 |

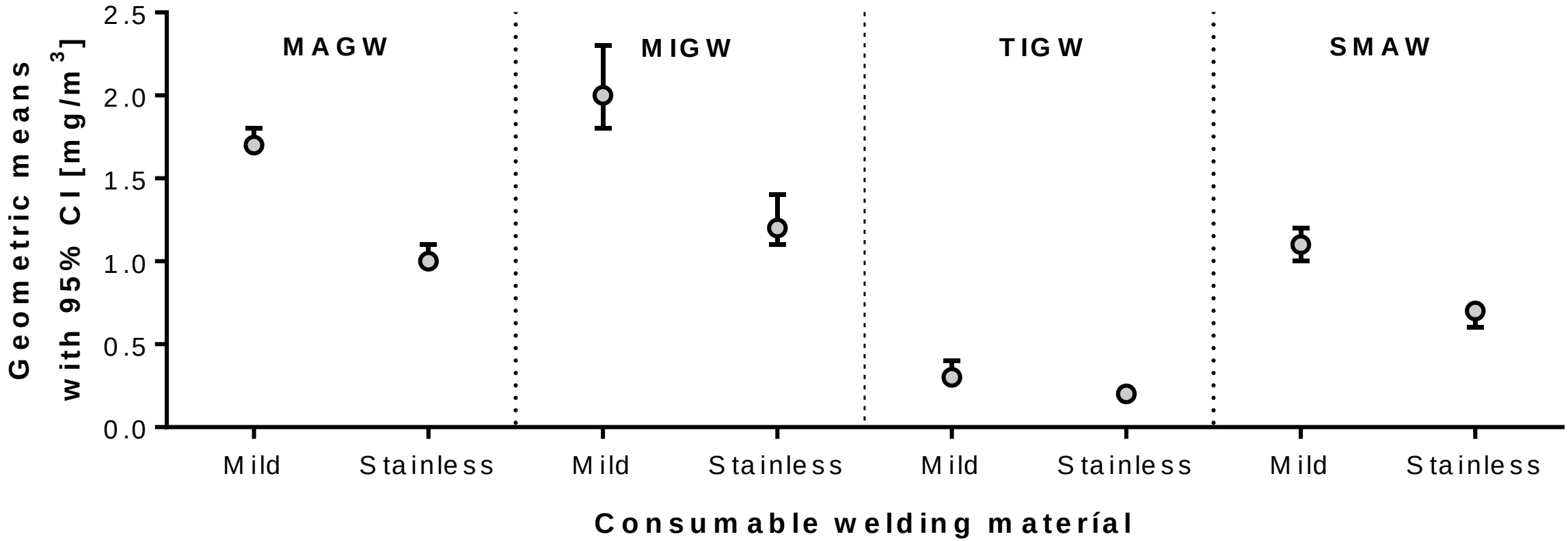
*GMs standardized to the median year and sampling time

# 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