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Investigating the Impact of Nanoparticle Production

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» Objectives

Overall: Development of a general model in LCA for the inclusion of occupational health effects from chemical and (nano)particle exposure

Specific: Examine the exposure in workplaces and assess the potential importance of occupational health effects to the total human toxicity potential

» Nanotechnology and LCA/LCM

- Attempts are being made in addressing the life-cycle impact of nanotechnology,but these are mainly in the area of energy.

  * **Energy consumption during nanoparticle production: How economic is dry synthesis?** Osterwalder et al., 2006. J*ournal of Nanoparticle Research, 8:1-9*

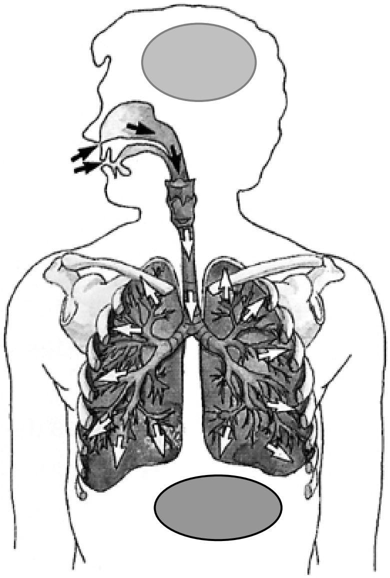
  * **Life Cycle Benefits of Using Nanotechnology To Stabilize Platinum-Group Metal Particles in Automotive Catalysts.** Lloyd et al., 2005. E*nviron. Sci. Technol., 39, 1384-1392*

  * **Life Cycle Economic and Environmental Implications of Using Nanocomposites in Automobiles.** Lloyd and Lave, 2003. *Environ. Sci. Technol. 37, 3458-3466*

- An LCA of nanotechnology, without the assessment of human health effects, is not complete and may miss an important impact

» Motivation: Health risks

- Large specific surfaces
  - Strong interaction with the body
- Points of entry into the body
  - Mainly **lung system**
- Effects
  - Known problems from exhaust particles
    - respiratory and cardiac problems (especially small particles)
    - peaks of exposure increase morbidity and mortality
  - Mechanisms are not well known
  - Poor knowledge of long term effects

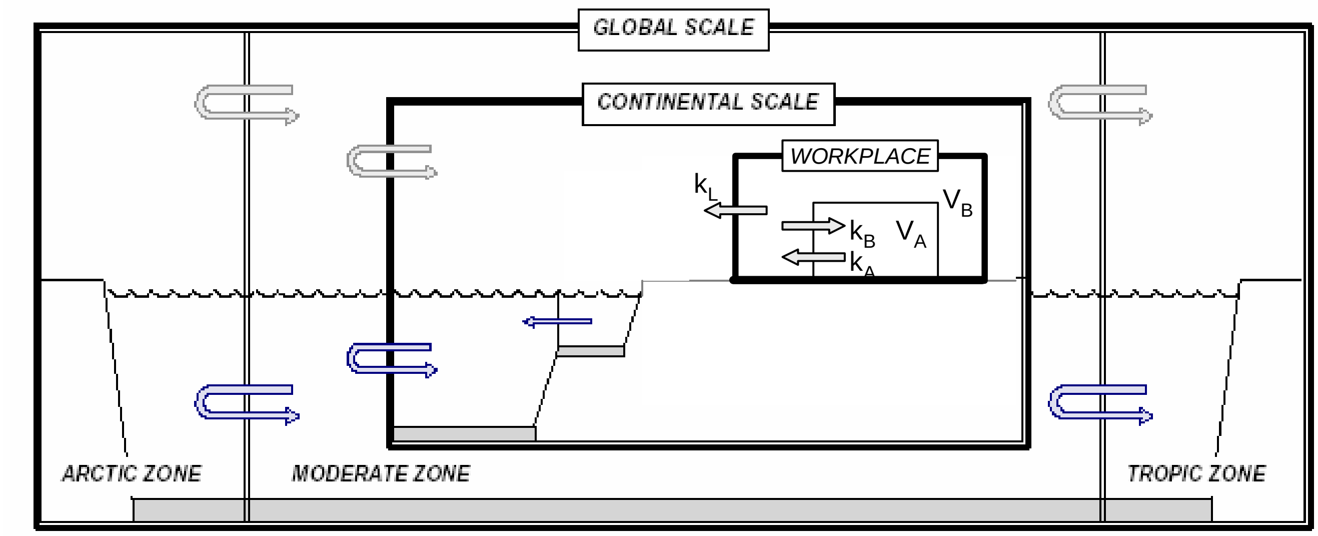


Reference: SUVA

➡ Exposure analysis as a first step of risk assessment

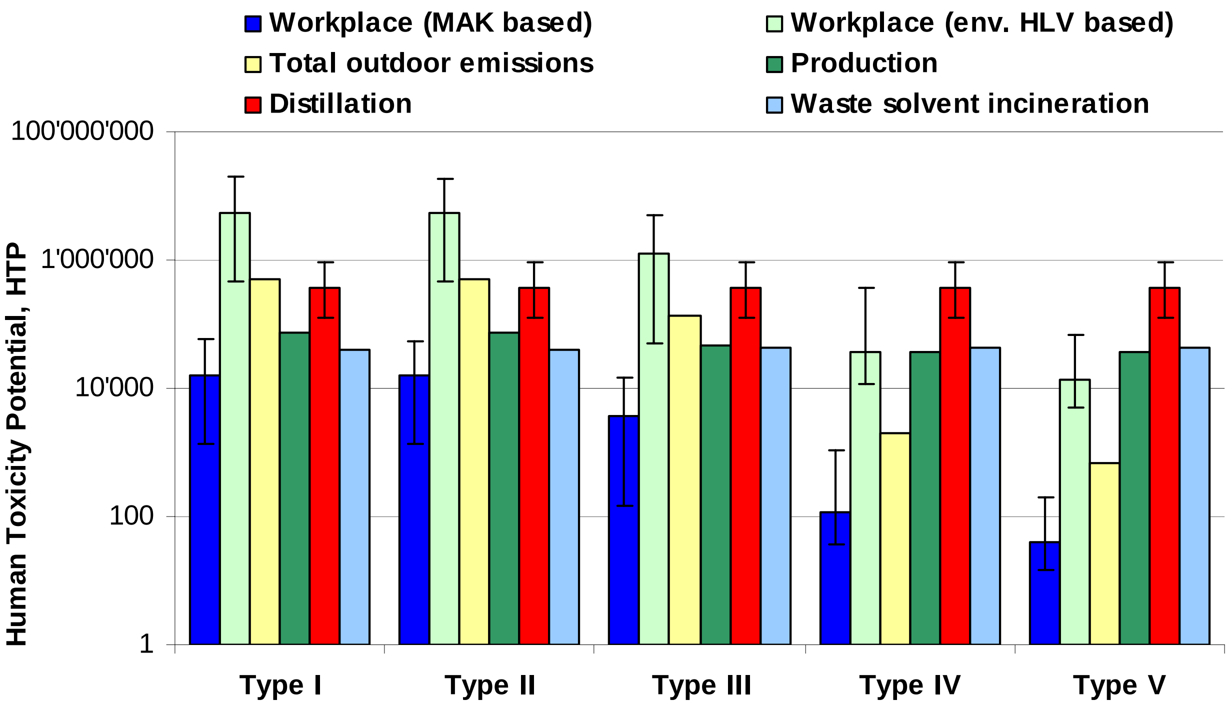
» Motivation: Occupational Exposure & LCA

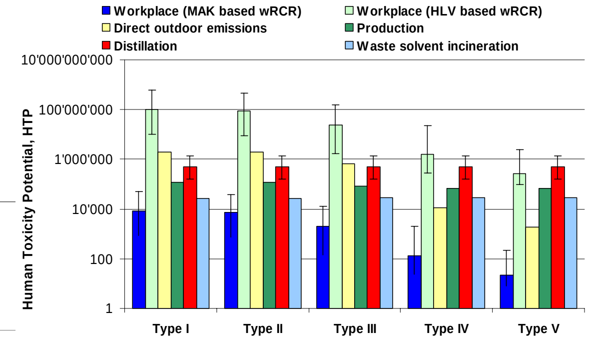
- Total emissions at steady-state, E_A, were estimated for each machine type and size
- Workplace environment embedded as a third scale in USES-LCA *(Huijbregts, 1999)*

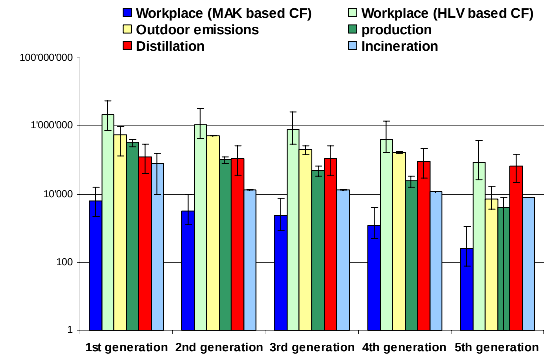


Reference: Hellweg et al., 2005. *Environ. Sci. Technol. 39, 7741-7748*

» Results LCIA: PCE Metal-Degreasing







→Workplace Exposure relevant compared to Outdoor Exposure

→ Workplace Exposure dependent on technology used

» Objectives: Nanoparticle Production

The key deliverables of the research project are:

- **Stage 1:**
- Experimental monitoring of the workplace environment and quantification of nanoparticle concentrations

- Identification, quantification and mitigation of the potential for workers' exposure relative to task.

- **Stage 2:**
- Development/validation of adequate particle exposure models.

- Completion of a Life-Cycle Assessment of the nanoparticle production process

» Methodology

- Size-distribution of particles present in workplace during production
- Spatial and temporal analysis of nanoparticle concentration
- Influence of air exchange, temperature and humidity
- Analysis of exposure potential during secondary work, i.e. maintenance, cleaning, sieving, packaging
- Analysis of efficiency of workers' protection methods, mainly breathing masks and overalls

» Instrumentation

- **Condensation Particle Counter (CPC)** [Model 3007, TSI Inc.]
  - Number concentration [p/cm3] for particles from 10 to 1000 nm

- **Scanning Mobility Particle Sizer (SMPS)** [Model 3934, TSI Inc.]
  - Instrument with a condensation particle counter [Model 3022A, TSI Inc.] and an electrostatic classifier [Model 3071, TSI Inc.]
  - Particle size distribution of particles in the range of 7 to 1000 nm

- **Optical dust monitor (DustTrak)** [Model 8520, TSI Inc.]
  - Mass concentration [mg/m3] of PM1, PM2.5 and PM10

- **VelociCalc Plus** [Model 8386A, TSI Inc.]
  - Air velocity: 0 to 50 m/s, Temperature: -10 to 60°C, Humidity: 0 to 95%

- **Air velocity: Transducers** [Model 8450, TSI Inc.]
  - Air velocity: 0 to 2.0 m/s

» Emission Scenarios

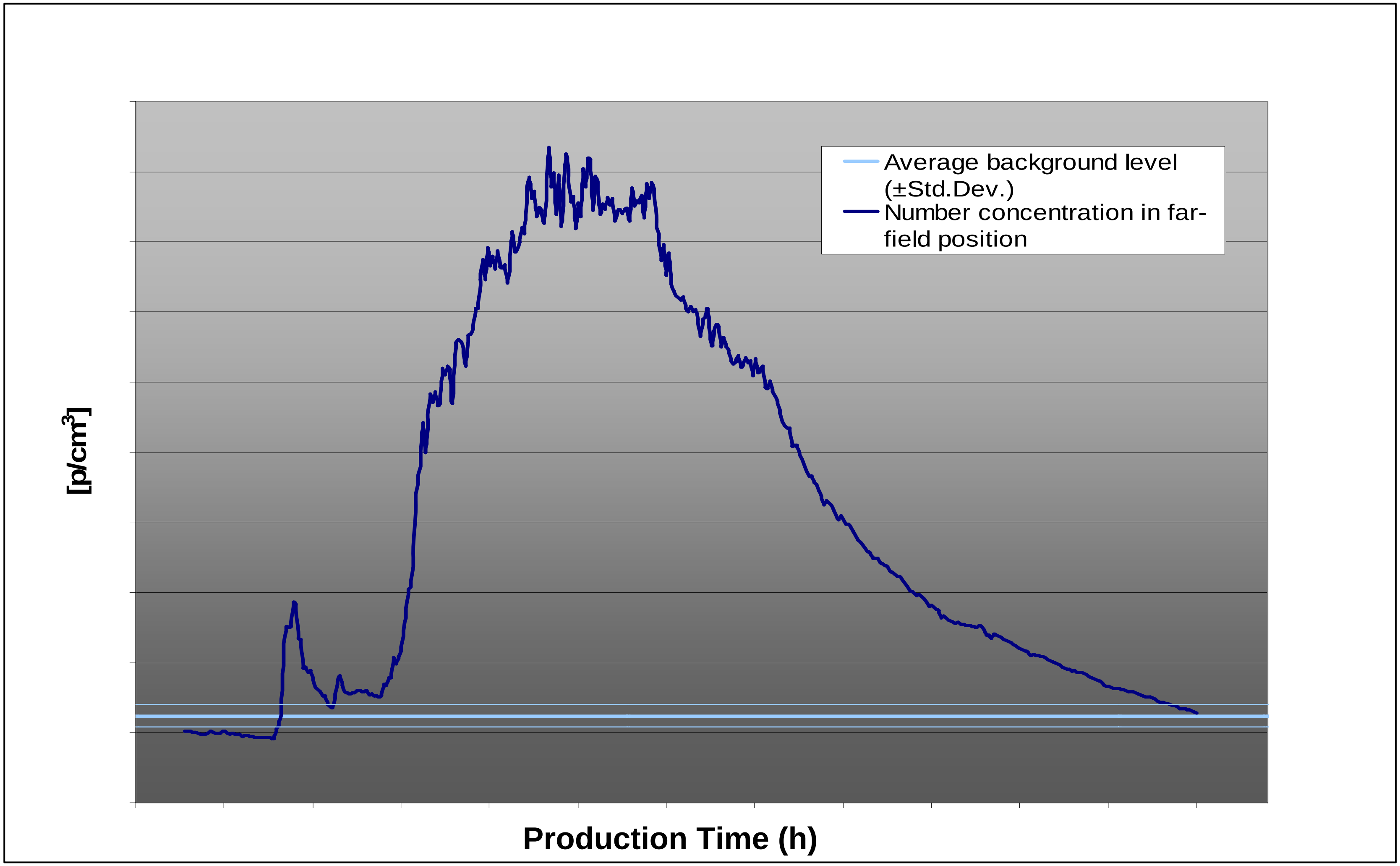
- Workplace emissions to air are a function of:
  - Particle properties
  - Type of application and technology
  - Ambient conditions

- Expected emissons in nanoproduction facilities
  - Diffuse sources, E_{c1}
  - Repetitive/periodic processes, E_P
  - Maintenance operations, E_M

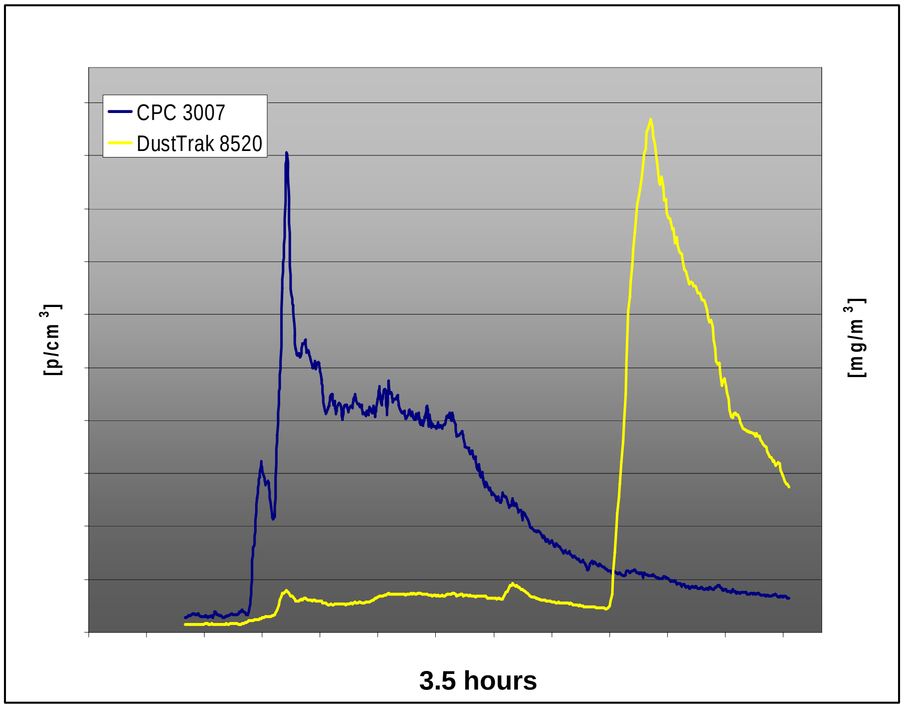
Total emissions into workplace,

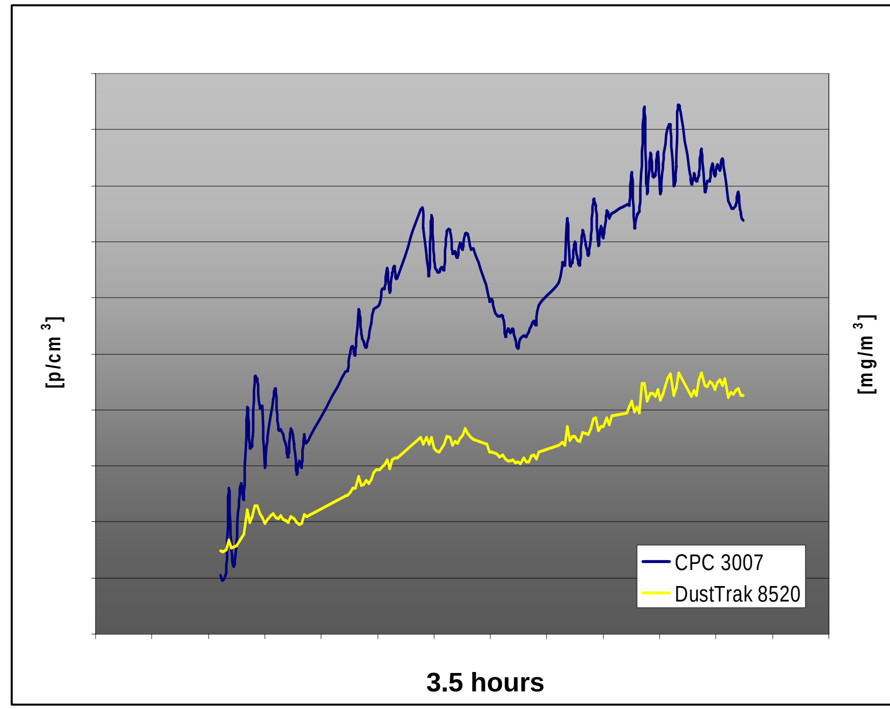
$$E_A = E_{C1} + E_P + E_M$$

» Production: Number Concentration

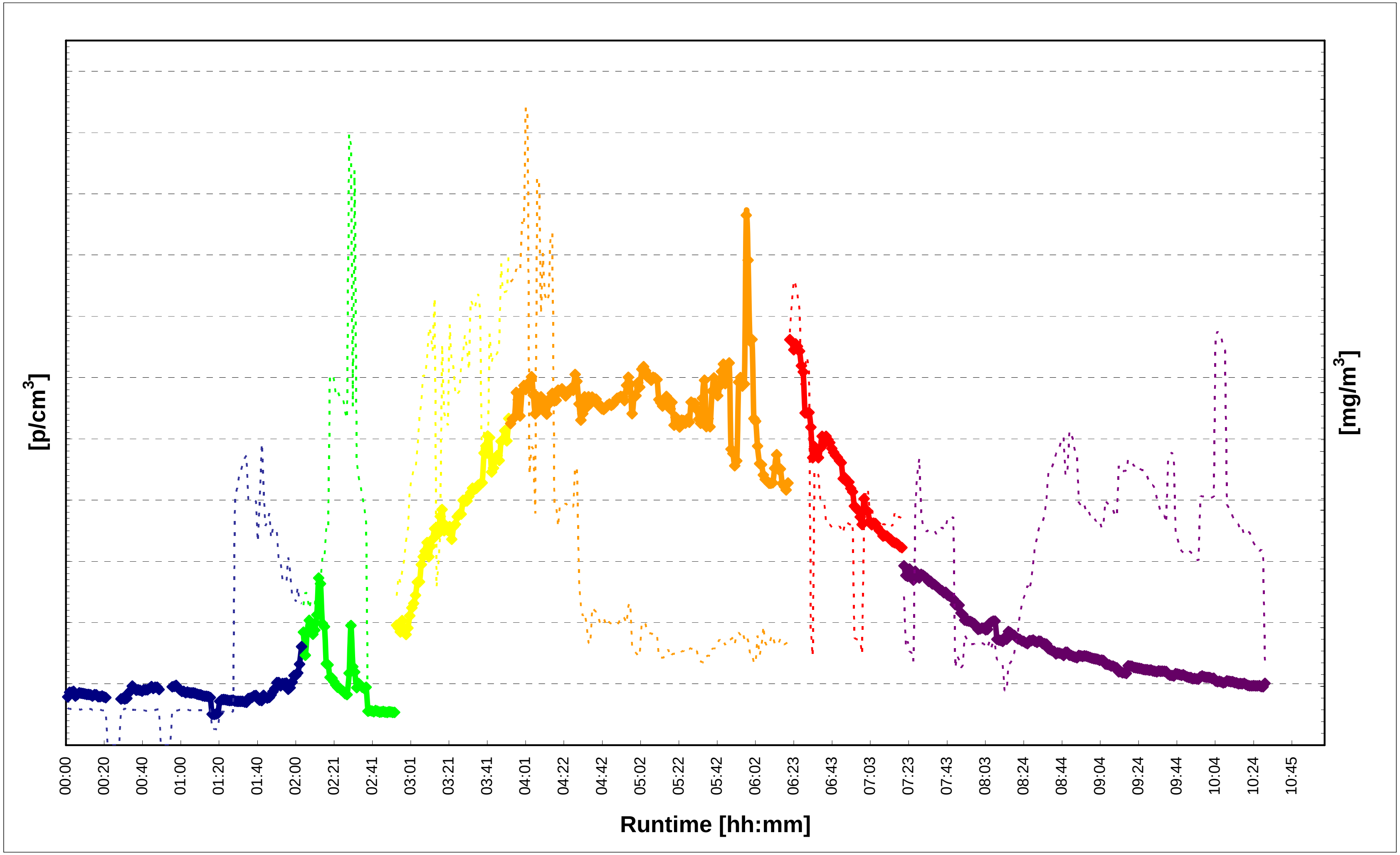


» Production: Mass versus Number





» Concentration Profile: Number versus Mass

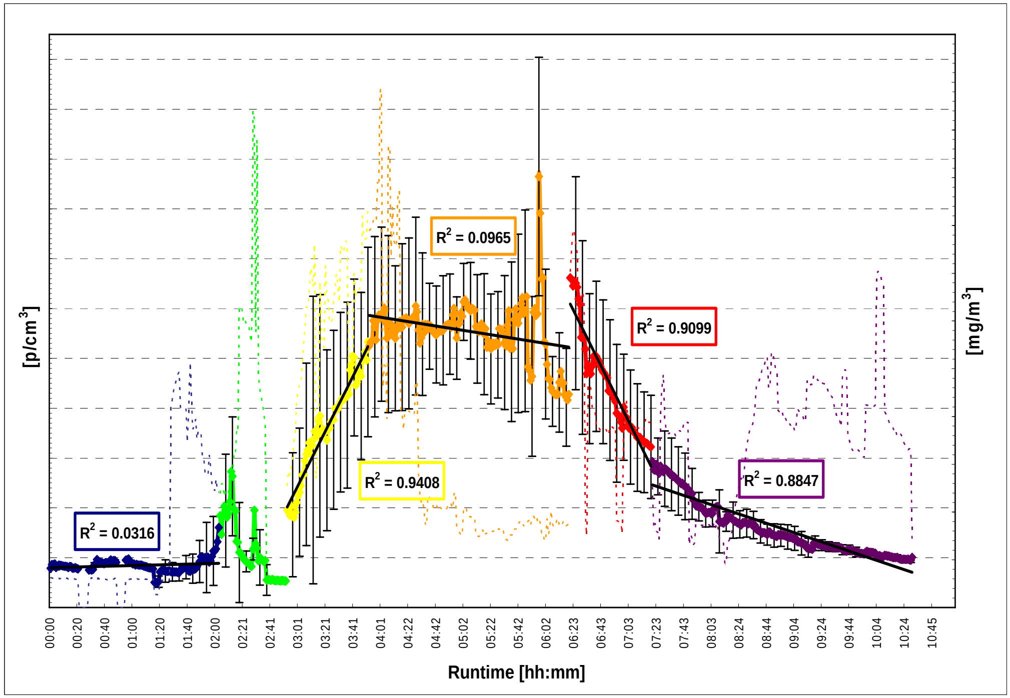


» Exposure Modeling: Parameter Estimation

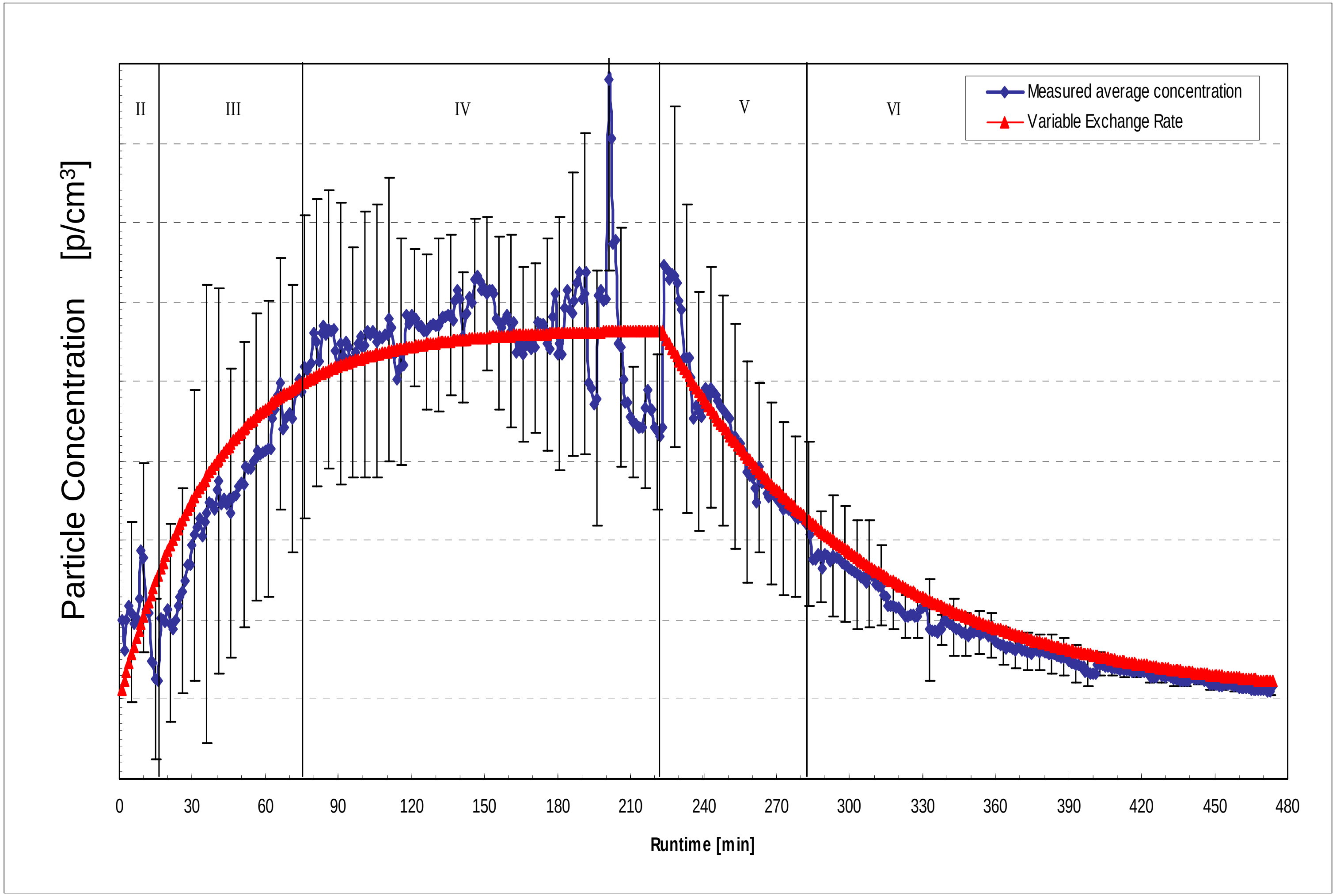
- Emission rate, *E*
  - Calculation from the slope in the starting phase:
  - *E* = constant throughout production

    E = 0 after production stop

- Air exchange rate, k_{vent}
  - Exponential decline
  - Early and advance linear decline
    - $k_{vent} = 0.706\ h^{-1}$



» Exposure Modeling: Results



- One-box, well-mixed model was applied
- Model matches values of steady-state and concentration decline

» Outlook

- Instrumentation and technology is available for the characterization of exposure to nanoparticles down to 4 nm

- Indoor exposure models exist than can be coupled to established outdoor exposure models

- Requirements for impact assessment to human health in LCA
  - further toxicological data to establish a threshold value for nanoparticle exposure
  - consensus on a specific method, i.e. number versus mass, aerodynamic diameter, etc.

» Conclusions

- Concentrations from the production of nanoparticles in occupational environments are measured:

  → relevant to health effects

- Occupational legal thresholds are in mass and based on bulk material properties, while specific properties and reactivity of nanomaterials are attributed to size, surface properties and surface area → non-mass based threshold values

- Necessity: to examine health effects of nanoparticles from indoor exposure as well as outdoor, as this can have a significant impact throughout the life-cycle

Thank you for your attention!

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