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# The MARKOPOLO indoor/outdoor project:
## Real-time assessment of residential ultrafine particle exposure indoors and outdoors

**Marloes Eeftens**, Fiona Streit, Laura Vallan, Marc Grünig, Eric Twomey, Martin Röösli

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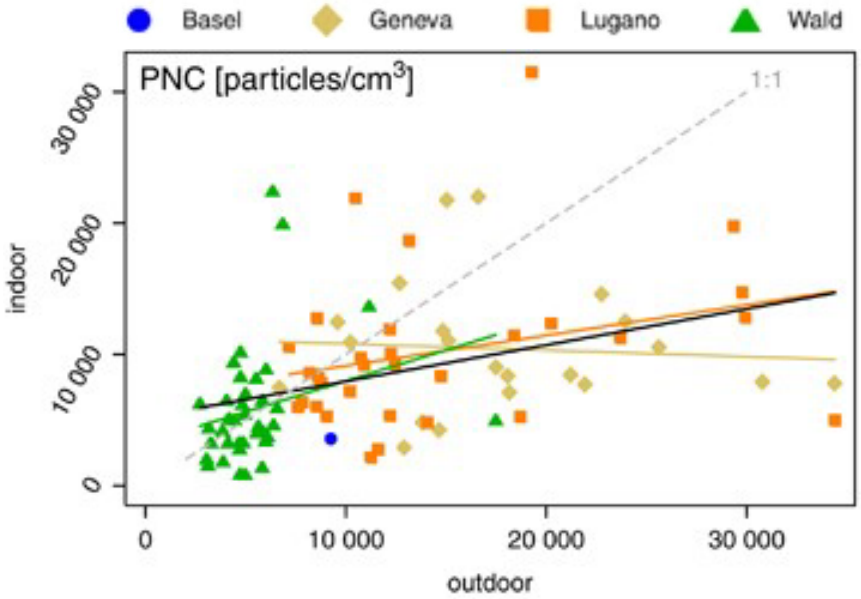
# Introduction

- Few studies have investigated concentrations of ultrafine particles of mixed outdoor and indoor origin in typical, real-life households

- Limitations of previous projects:
  - Indoor measurements in rooms which are not used
  - Limited information about residents' indoor behaviour
  - Consider only the average of a week-long measurement / annual average




From: Meier, Eeftens, …, Künzli (SAPALDIA), *JESEE*, 2015



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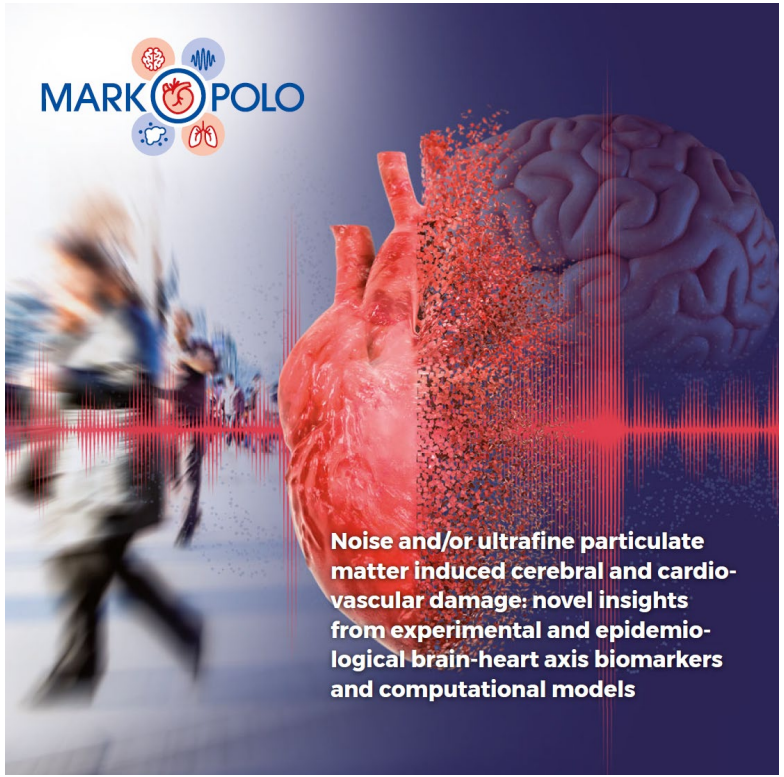
# The Markers of Pollution (MARKOPOLO) project

- Noise and ultrafine particulate matter
- Cerebral and cardiovascular diseases
- Experimental and epidemiological studies




Activities at Swiss TPH in the first year:
Stationary and mobile measurements,
indoor & outdoor UFP exposure characterization



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# Aim

- To investigate how indoor air quality depends on:
  - Outdoor air quality
  - Everyday behaviour of the residents
  - Building characteristics

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# Methods: indoor / outdoor measurements

- Simultaneous measurements:
  - Indoors in the main living room
  - Outdoors on the balcony / in the garden
- At 60 homes in Basel (CH) and surroundings:
  - 17 Homes which use wood for heating
  - 18 Homes on major streets
  - 16 "Minergie" homes (energy efficient)
  - 17 Normal "control" homes
- In two seasons:
  - 7 days in winter (heating season)
  - 7 days in summer (non-heating season)

Indoor Setup

Outdoor Setup



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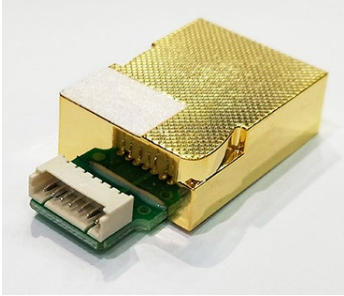
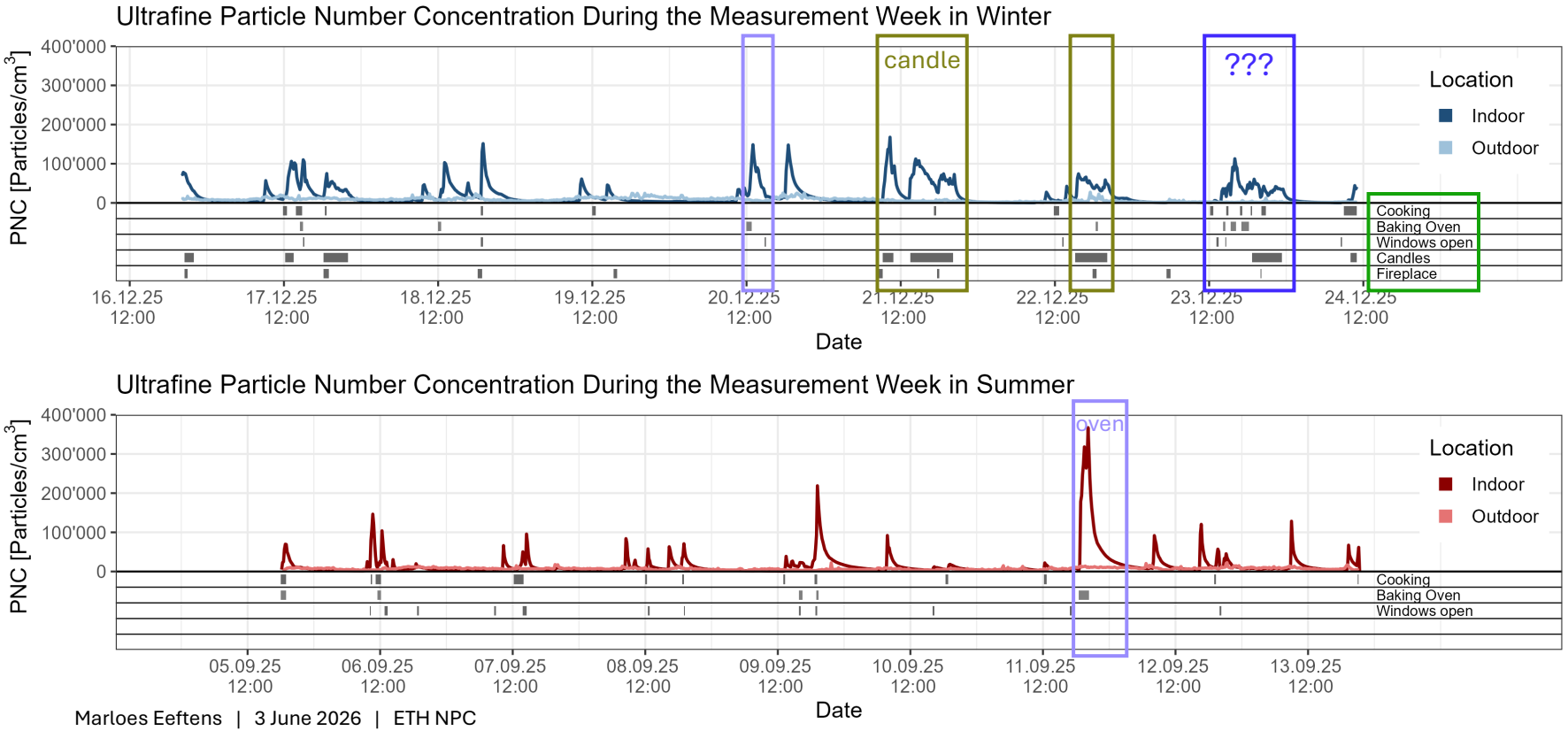
# Methods: equipment

- Ultrafine Particle Number Concentration (PNC): miniDiSC's
- $PM_{2.5}$ [µg/m³]: ZH03B Laser Dust Sensor (affordable sensor)
- $CO_2$: [ppm]: MH-Z19C NDIR (affordable sensor)
- Temperature (°C): Sensirion SHT30 (affordable sensor)
- Relative humidity (%): Sensirion SHT30 (affordable sensor)
- $NO_2$ [µg/m³]: Passam passive tubes
- BTEX [µg/m³]: Passam passive tubes

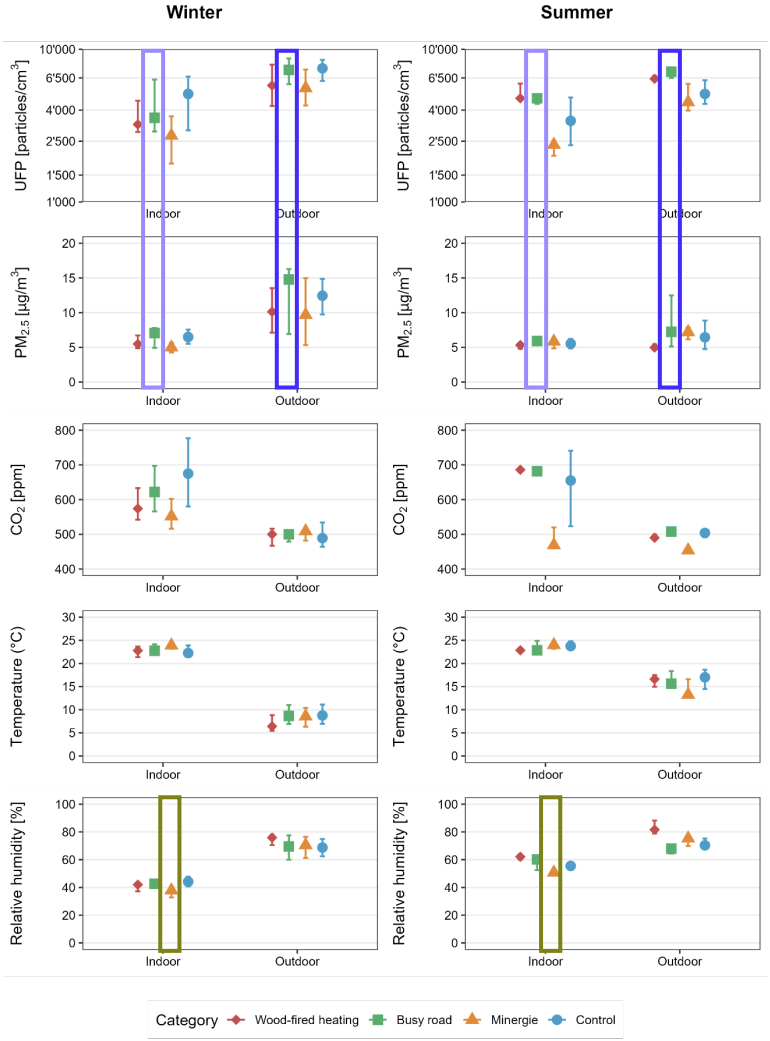
# Results: example measurement + household diary



# Results: overall trends

- PNC and $PM_{2.5}$ are higher outdoors than indoors
- Homes near major roads have relatively high PNC and $PM_{2.5}$
- Some Minergie-residents mentioned “dry air” in winter, but no clear effect overall

Median and interquartile range (P25 – P75) of household-specific 1-week median concentrations



# Statistical modelling

log(indoor PNC) ~ log(outdoor PNC) * ventilation + behaviour + housing characteristics

Aggregated to 10-minute averages

Outdoor concentration affects indoor concentration.

If the window is open, we would expect outdoor concentration to have a larger effect.

- Cooking
- Oven use (baking)
- Window opening
- Candle burning
- Fireplace use

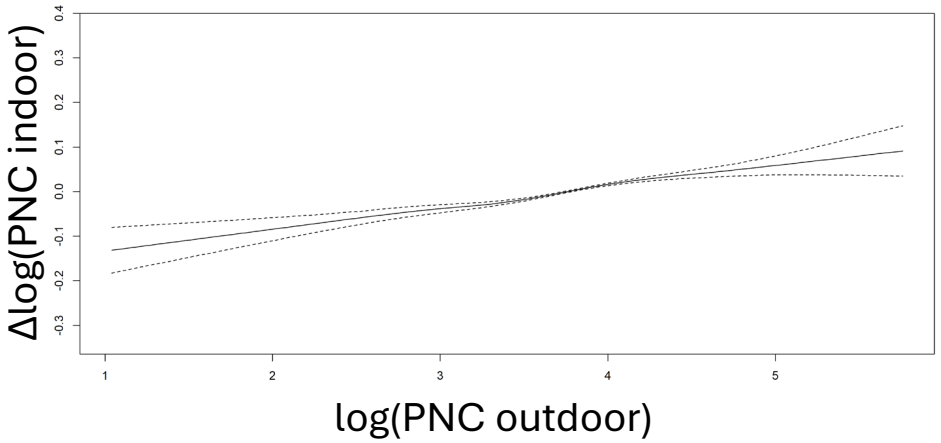
- Age of the building
- Nr. of occupants
- Gas stove vs electric
- Pets, etc

By evaluating all these drivers simultaneously, effects are mutually corrected

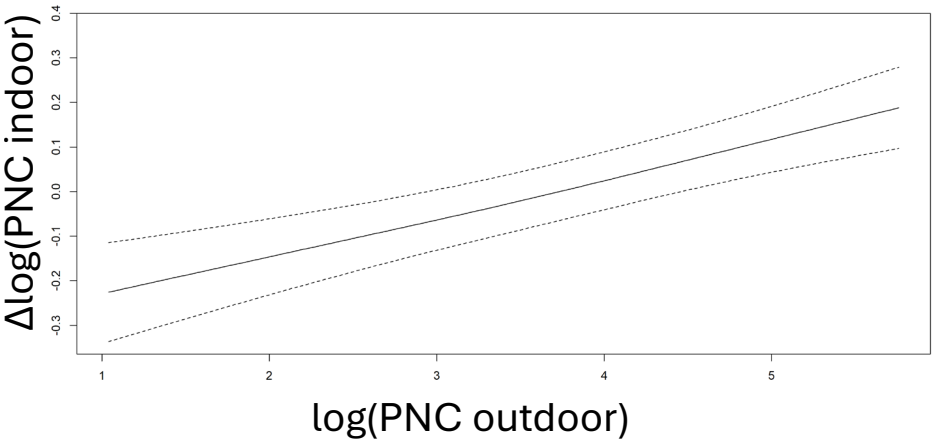
# Results: influence of outdoor PNC on indoor PNC

- Outdoor PNC and indoor PNC are positively correlated
- The influence of outdoor on indoor is stronger if the window is open (steeper curve)

**Windows closed**




**Windows open**



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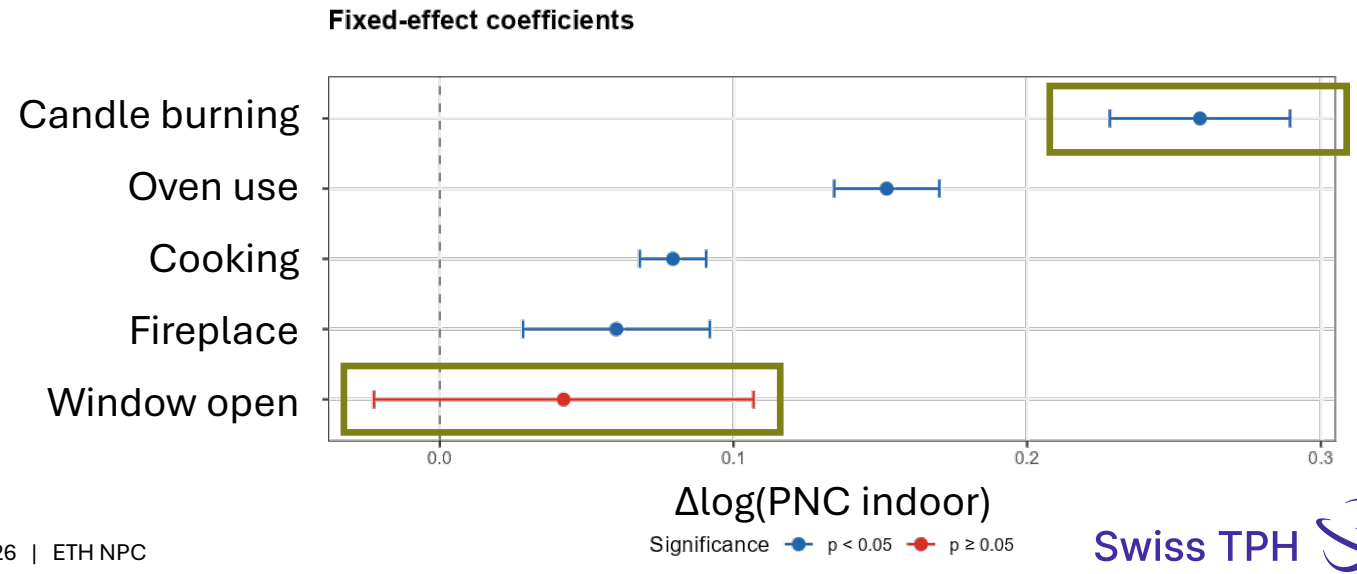
# Results: effects of residents' behaviour

- During the time they are happening, common activities affect PNC
- Candle burning causes most additional PNC, relative to other activities
- Effect of window opening can go in either direction



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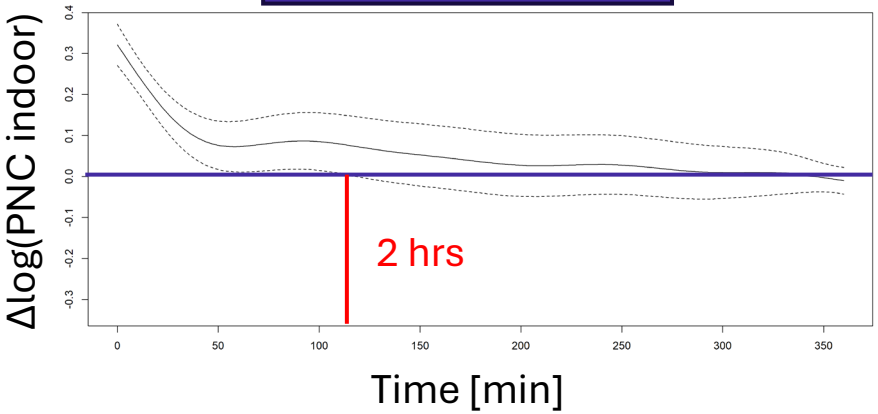
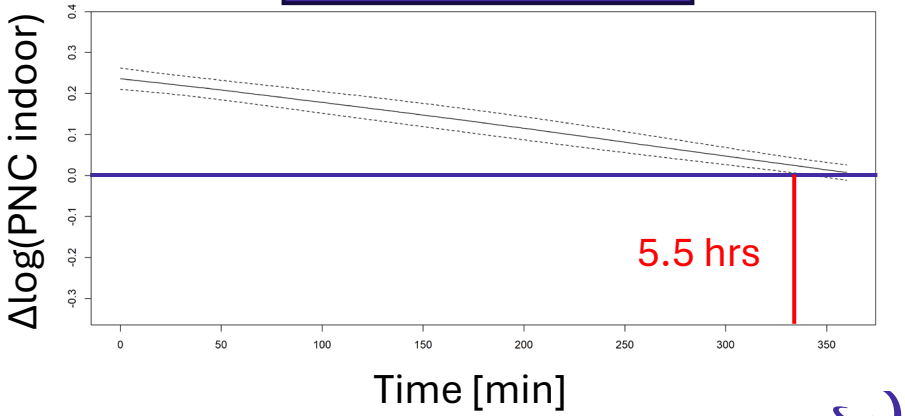
# Results: effects of residents' behaviour (decay)

- After activities are done, PNC concentrations decay
- Decay is initially steep for candle-related PNC, then levels off
- PNC from oven-use decays more gradually
- PNC stays significantly elevated for several hours beyond finishing the activity

Candle burning




Oven use



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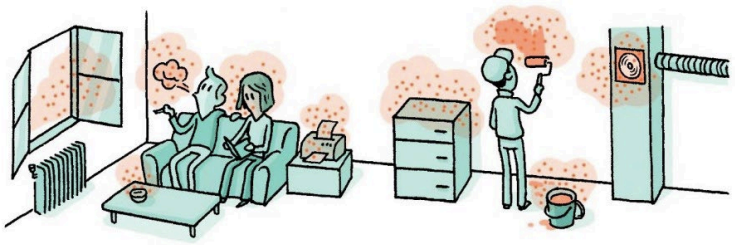
# Conclusion

- Outdoor PNC is typically higher than indoor PNC – on average!
- But: indoor PNC is affected by personal behaviour – peaks exceed outdoor PNC
- Effects of home characteristics on PNC is relatively small – no/very minor effects of:
  - Age of the building
  - Number of occupants
  - Gas stove vs. electric
  - Pets, etc.

**Notes / disclaimers:**

- Preliminary results, more measurements ongoing
- Next steps: additional pollutants
- Observational study: real-life exposures



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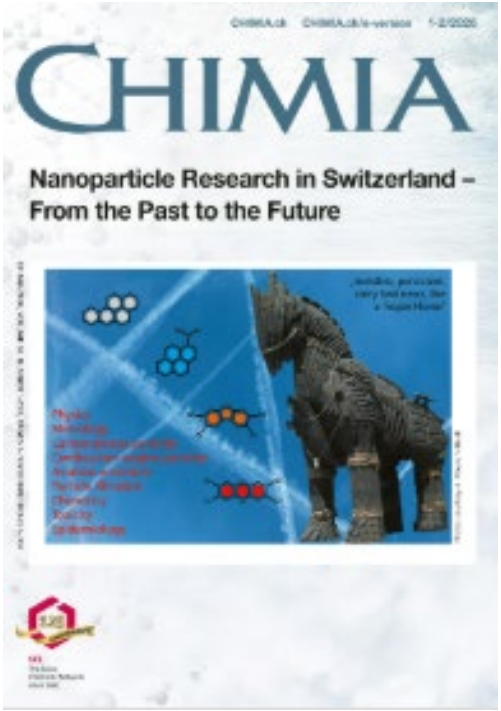
# Check out our CHIMIA contribution here



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## Airborne Ultrafine Particles: Real-life Exposure Patterns, Epidemiological Evidence and Regulatory Responses in Switzerland and Beyond

Marloes Eeftens[a,b,*], Eric P. Twomey[a,b], Fiona Streit[a,b], and Martin Röösli[a,b]

*Abstract:* Ultrafine particles (UFP) exhibit large spatial and temporal contrasts, and distinct physicochemical properties that enable deep lung penetration and systemic translocation, posing potential health risks. Despite mechanistic evidence from toxicological studies, large-scale epidemiological evidence remains limited due to sparse monitoring and complex exposure assessment. Switzerland has contributed substantially to UFP research through measurement campaigns, mobile monitoring, and modelling studies, which improved understanding of spatial and temporal exposure contrasts. Emerging findings suggest associations between long-term UFP exposure and cardiovascular indicators, though epidemiological evidence for short-term associations with mortality and morbidity remains weak. Ongoing Swiss and European projects aim to refine high-resolution spatiotemporal models, assess population-level health impacts, and inform future air quality standards and regulatory frameworks for UFPs.

**Keywords:** Air pollution · Epidemiology · Health effects · Particle number concentration · Switzerland · Ultrafine particles

***Marloes Eeftens*** leads the Sensoring and Environmental Epidemiology research group at the Swiss Tropical and Public Health Institute (TPH). She specializes in measuring and modelling environmental exposure to various pollutants, including air pollutants, ultrafine particles, elemental composition of particulate matter, temperature, non-ionizing radiation, and their health impacts. She has previously studied spatial, temporal, and indoor/outdoor contrasts in real-life settings within the SAPALDIA study (Swiss Cohort Study on Air Pollution and Lung and Heart Diseases in Adults) and is currently coordinating the Swiss TPH team within the international MARKOPOLO (Markers of Pollution) project, which aims to study the long-term and acute cardiovascular health effects of ultrafine particle exposure, among other pollutants.

***Eric Twomey*** has a background in medicine and previous clinical experience as a physician at the University Hospital Zurich, he holds a Master of Public Health with a focus on environmental health and is currently pursuing his PhD in Environmental Epidemiology at the University of Basel. At the Swiss Tropical and Public Health Institute, he is part of the MARKOPOLO project, where his research focuses on measuring and modelling ultrafine particle concentrations across Switzerland and assessing their associations with overall mortality, neurovascular diseases, and brain cancer.

***Fiona Streit*** holds a Master's degree in Health Sciences and Technology and is currently an intern at the Swiss Tropical and Public Health Institute in the Sensoring and Environmental Epidemiology research group. Her work within the MARKOPOLO indoor/outdoor project focuses on the impact of building characteristics and everyday behaviour on indoor UFP concentrations.

***Martin Röösli*** has a background in Environmental Science, is a full professor for environmental epidemiology and head of the Environmental Exposures and Health Unit at the Swiss Tropical and Public Health Institute. His research deals with a broad range of public health relevant national and global environmental health issues, including air pollution, noise, non-ionizing and ionizing radiation, radon and heat. He is conducting exposure assessment studies, epidemiological research and health risk assessments including systematic reviews in Switzerland and Europe. He serves as an advisor to a number of national and international public advisory and research steering groups concerning the potential health effects of environmental risk factors.

### 1. Introduction

Much like clinical studies that compare the effects of a drug to a placebo, environmental epidemiology studies rely on exposure contrasts to assess the impact of pollutants on health. These

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Eeftens, Twomey, Streit, Röösli, *CHIMIA*, 2026



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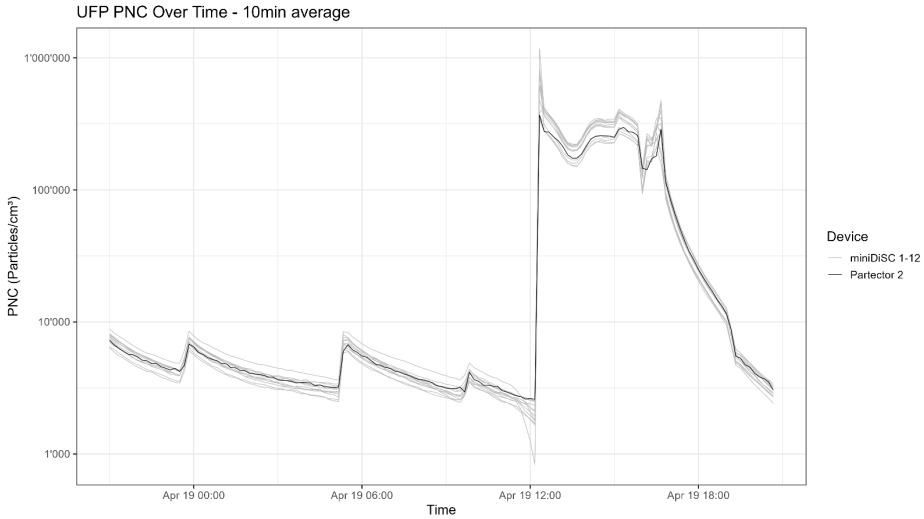
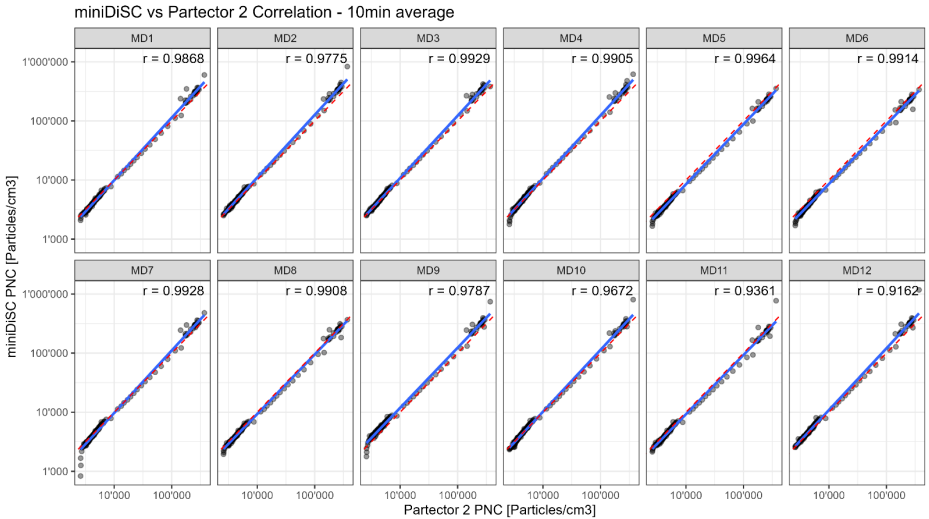
# MiniDiSC's vs. Partector 2 Pro



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