Sources of airborne particles indoors, including outdoor-to-indoortransport, their behaviour and exposure in indoor environments

Aneta Wierzbicka

Ergonomics and Aerosol Technology, Lund University, Sweden

We are exposed to air pollutants mainly inside the buildings

How much time do we spend indoors?

Average time spend daily at given locations (%)

	USA	Canada	Germany	European cities (Expolis study)	Korea
Total time spend indoors (home, office, factory, school, store, mall, bar, restaurant)	87	89			
Indoor at home	65	70	65	56 - 66	59 - 67
In vehicles	6	5			7
Outdoors	7	6			

On the basis of data from:
Matz et al., 2014, Int. J. of Environ. Res. And public Health, 11, 2108-2124
Yang et al., 2011. Journal of Exposure Science and Environmental Epidemiology, 21(3), pp.310-316.
Schweizer et al., (EXPOLIS) 2007, Journal of Exposure Science and Environmental Epidemiology, 17, 170–181
Klepeis et al., 2001, Journal of Exposure Analysis and Environmental Epidemiology, 11, 231-252
Brasche and Bischof, 2005, International Journal of Hygiene and Environmental Health, 208, 247-253

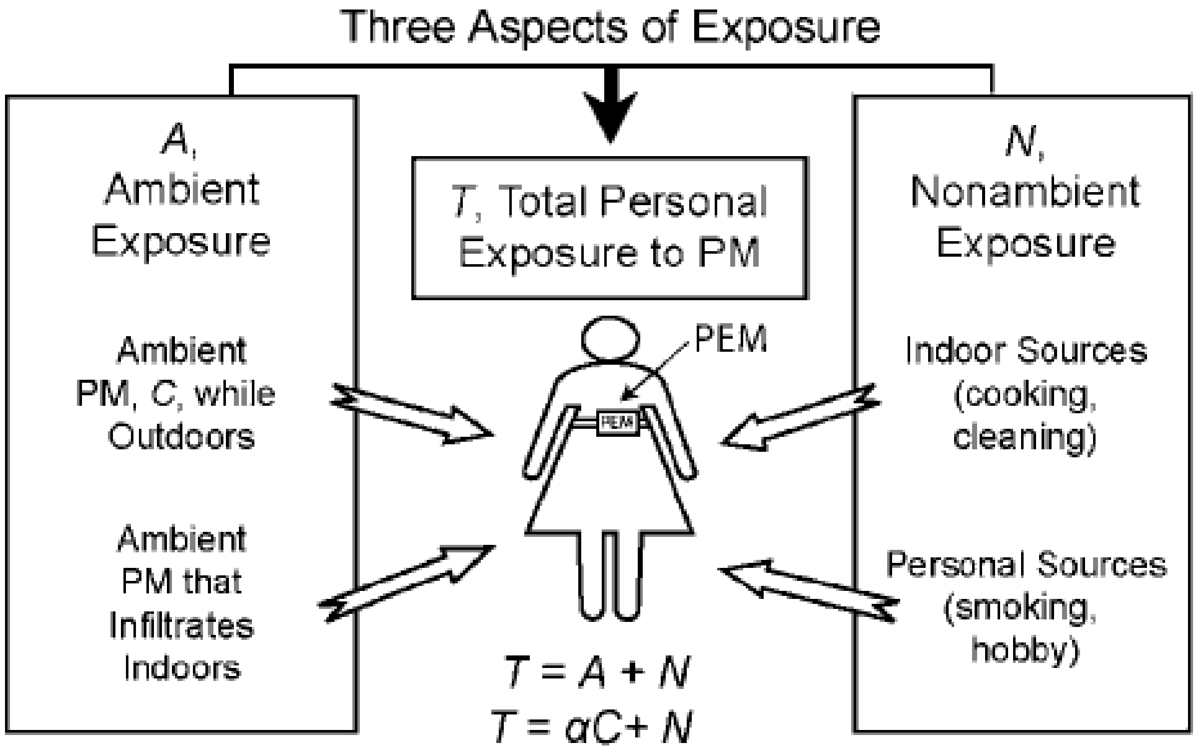


Figure 1. Total personal exposure has ambient and nonambient components.

PEM - Personal Exposure Monitor

C ambient PM concentration

From: Wilson W. and Brauer M., 2006, Journal of Exposure Science and Environmental Epidemiology Vol. 16, p. 264-274

Airborne particles in indoor environments

- Penetration from outdoors, which depends on
  - ✓ outdoor concentrations
  - ✓ ventilation type, filtration type (if any)
  - ✓ type of the building, tightness of the building envelope
  - ✓ airing practices
- Indoor sources (particles emitted directly or formed from gases), which depend on
  - ✓ Human activities
  - ✓ Frequency and intensity of the activities
  - ✓ Ventilation/kitchen hood use and its efficiency/airing practices

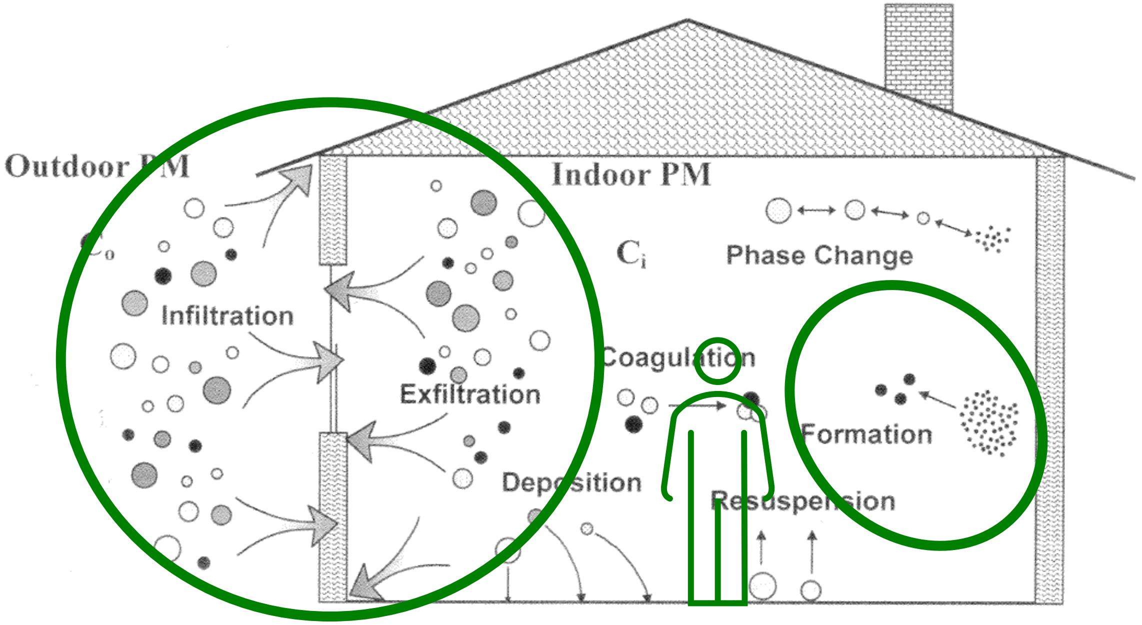


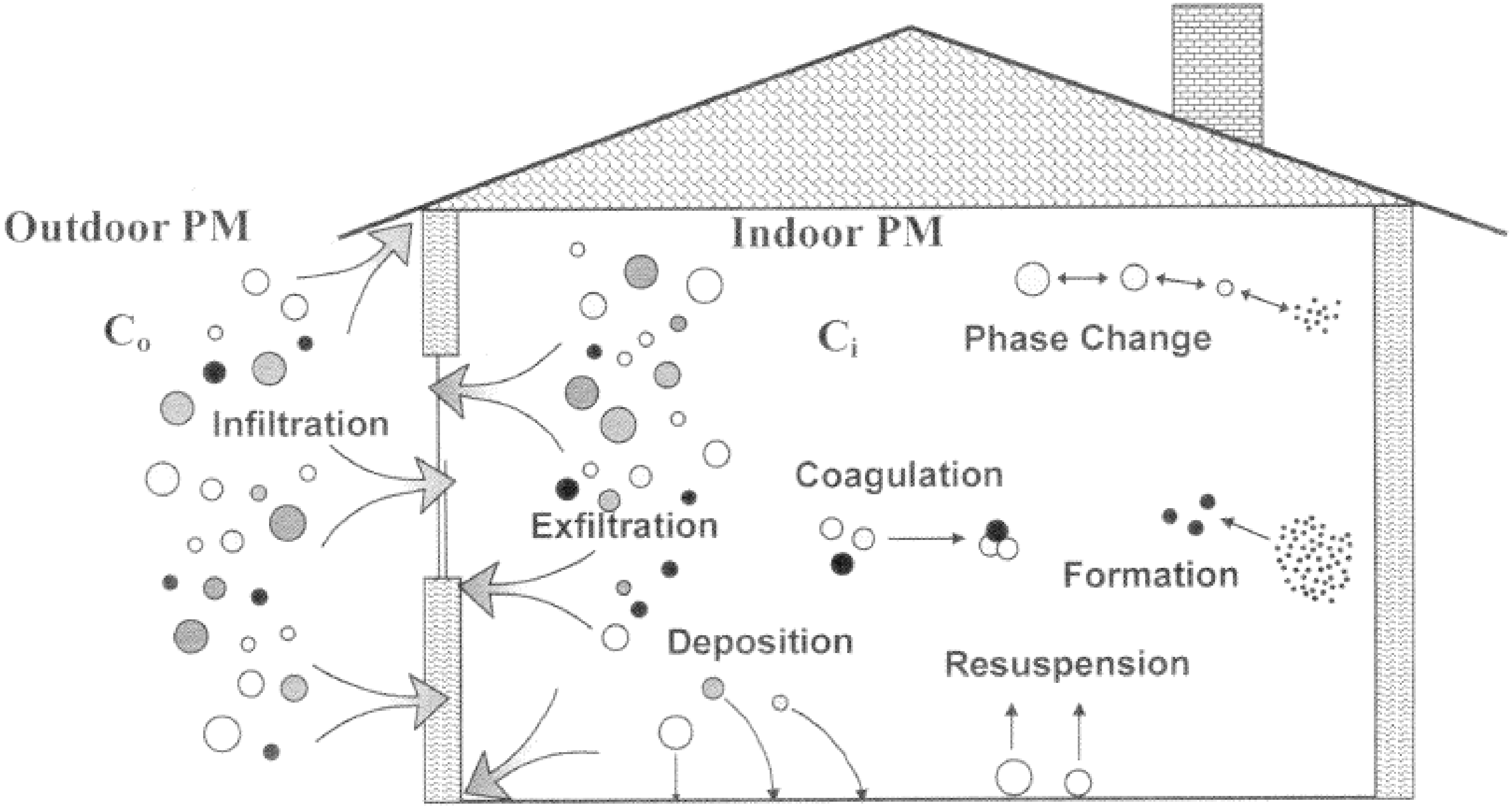
Figure 3. Schematic of particle transport, transformation, and removal processes in the indoor environment.

From: Thatcher et al., 2003, Aerosol Science and Technology, Vol. 37, No. 11, p.847-864

Indoor sources of airborne particles - examples

New products

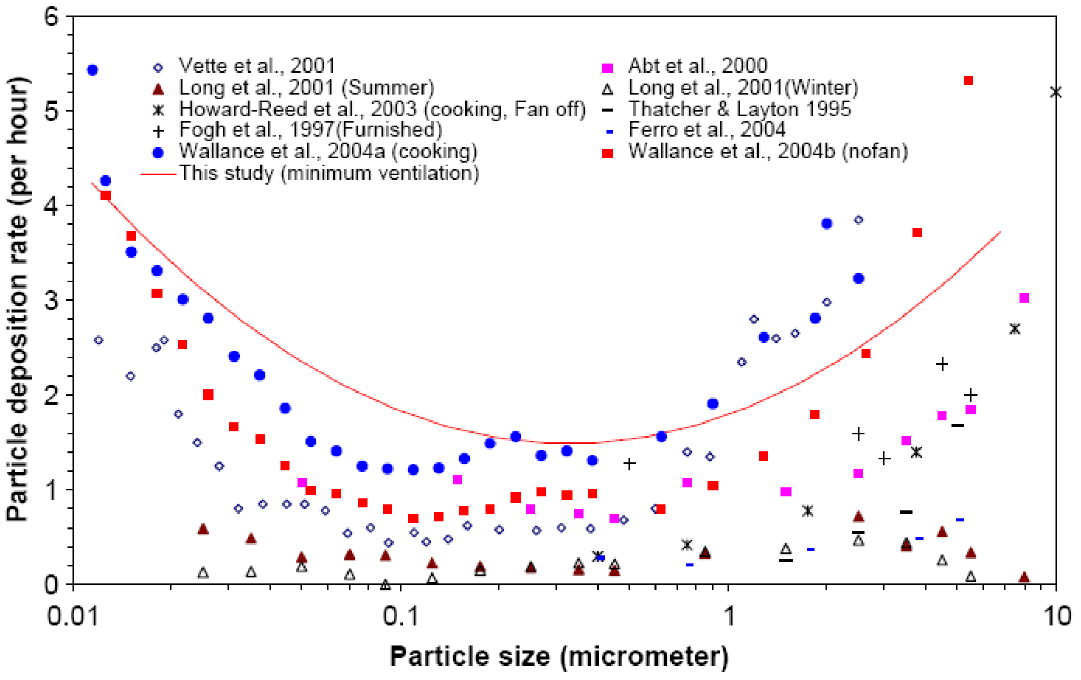
Airborne particles indoors – their behaviour



From: Thatcher et al., 2003, Aerosol Science and Technology, Vol. 37, No. 11, p.847-864

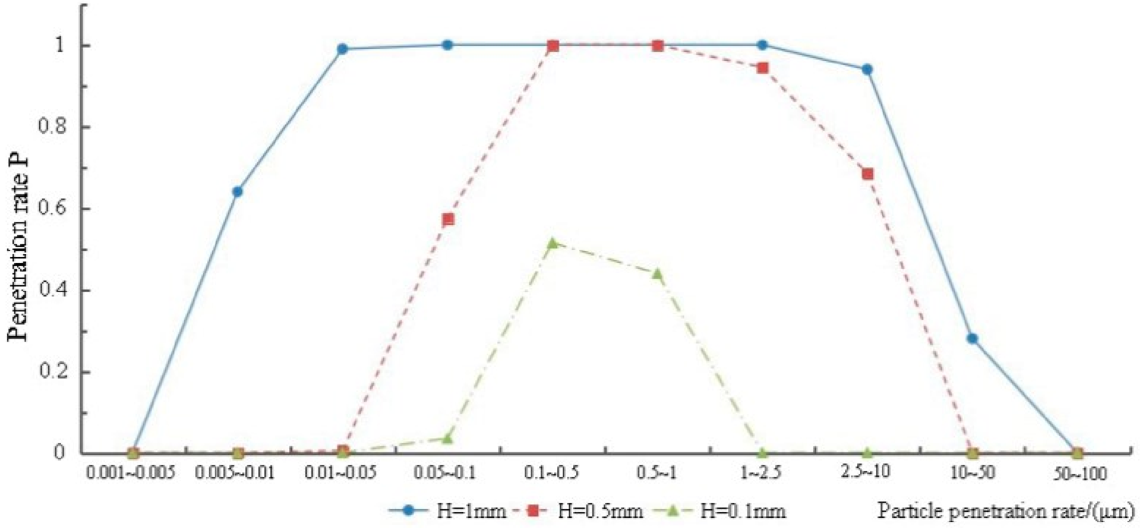
Airborne particles indoors – their behaviour

Deposition



From He et al., 2005, Atmospheric Environment, Vol. 39, p. 3891-3899

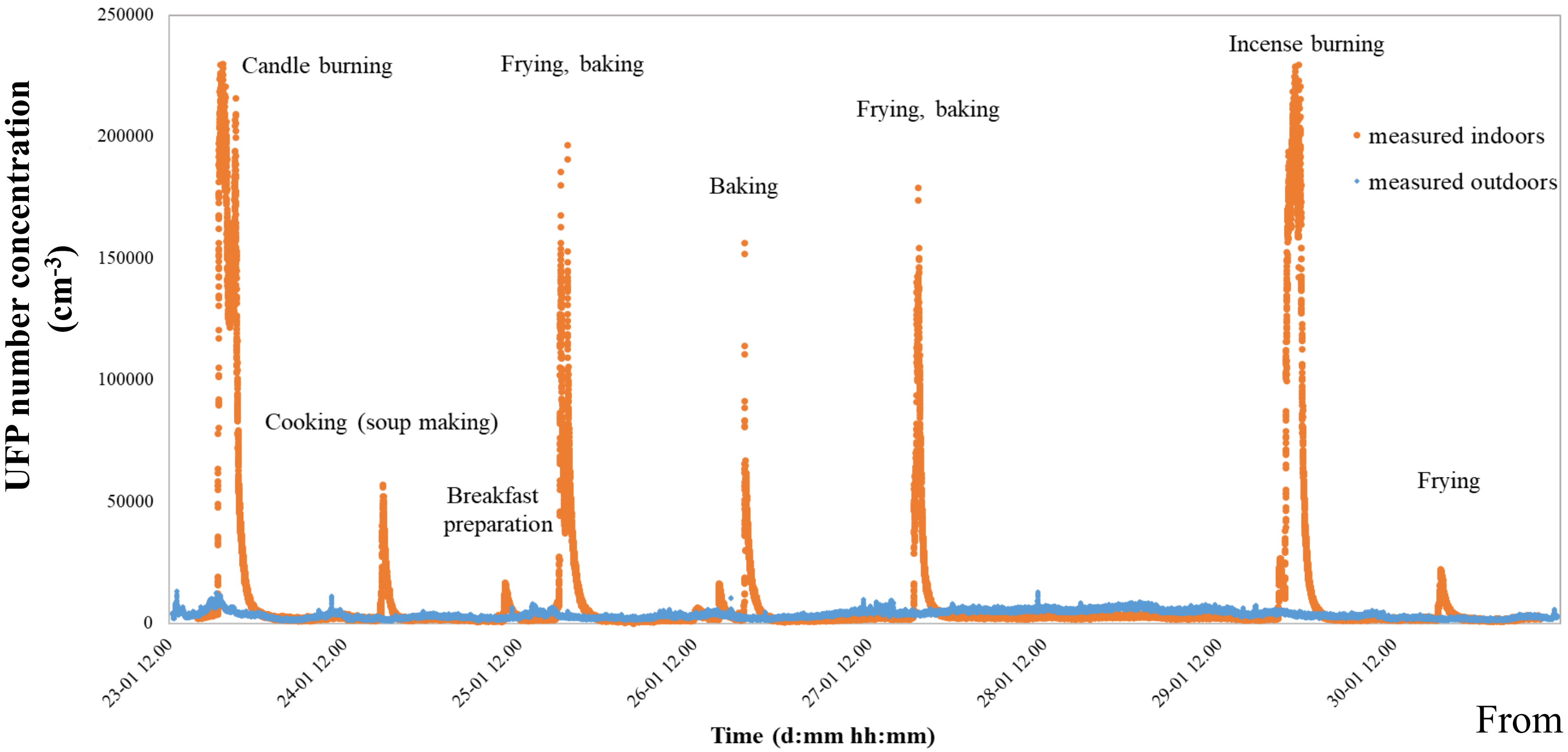
Penetration



Penetration rate between the particle size of gap height (Δ P = 10 pa, gap length = 3 cm)

From: Yu et al., 2020. Sustainability, 12(5), p.1708.

UFP number concentrations – indoors and outdoors



From Omelekhina et al. 2021, under review

Cooking and candle burning are dominating contributors to UFP particle number concentrations indoors

Contribution of indoor source to the residential daily UFP exposure accounts to 65% (Isaxon et al 2015, Bekö et al 2013)

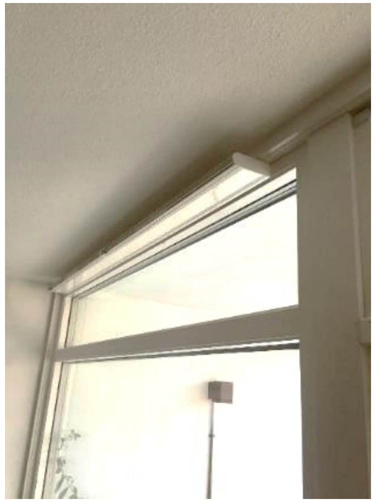
Energy renovation, occupants and role of kitchen hoods

Concentration of particles indoors after energy renovations

- Decreased penetration of outdoor particles
- Increased influence of indoor sources on airborne particles concentrations

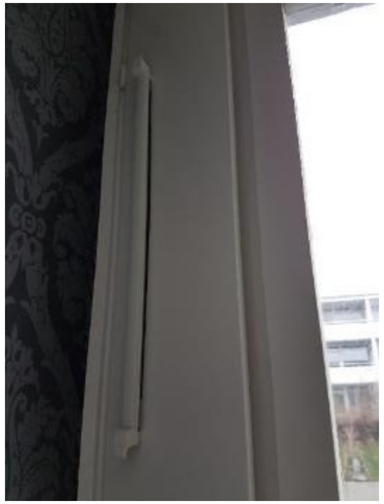
Before

After



Before

After



Kitchen hoods

- Their efficiency varies between 30% (!) and 98%
- Not integrated/automated with stove and oven use, require active switching on by the user
- Too loud – users choose not to use it
- Design (?)
- Recirculation – not suitable in kitchen

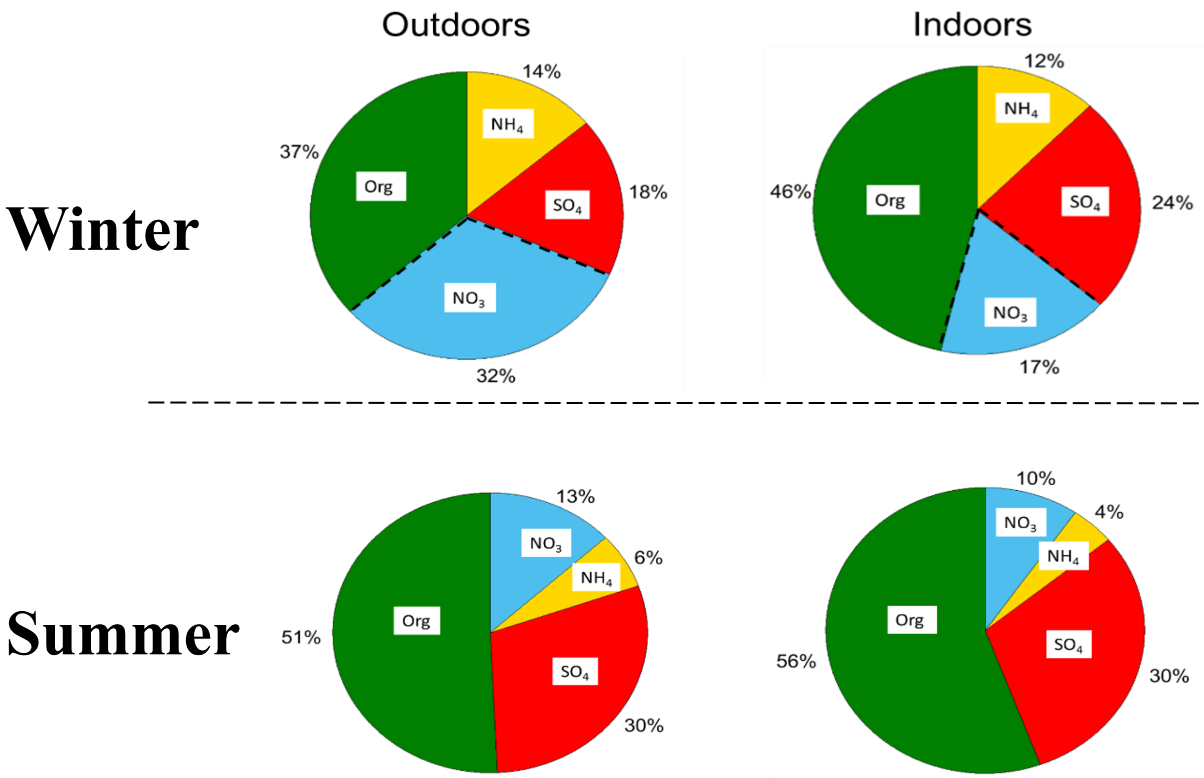
- If efficient and integrated with ventilation system can be simple and excellent way to remove particles when needed (on demand)





Seasonal differences in chemical composition (AMS) - non-occupancy

HEXACOMM

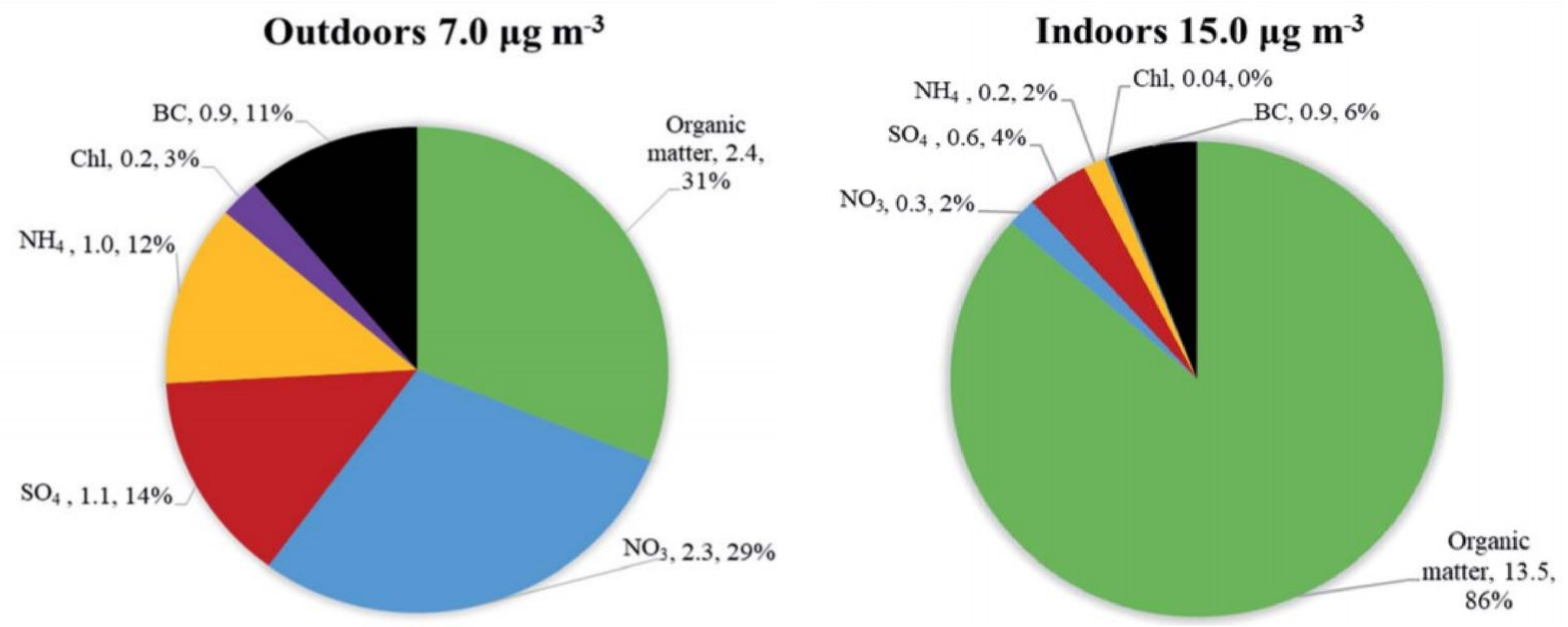


- **reduced share of NO_3^- indoors**

- **very similar proportions of chemical species indoors and outdoors**

Slide: courtesy of J. Ondracek. Talbot et al. 2017, *Aerosol and Air Quality Research*, 17: 653–665

Occupancy time



From: Omelekhina et al., 2020, Environmental Science Processes & Impacts, 22, 1382-1396

Cooking aerosols gained lots of attention – thanks to AMS and PMF cooking has been recognised as one of the main contributors to PM <u>outdoors (!)</u> (Allan et al, 2010, Mohr et al, 2012; Crippa et al 2013; Elser et al 2016)

Toxicity ?

Do the particles from indoor sources (or their mixtures) matter at all from health effects perspective?

Toxicity of indoor particles?

- Particles collected indoors had higher cytotoxic effects on mouse macrophages than particles collected outside **one single family house in Finland** (Happo et. al., 2013, 2014)
- Long et al, 2001 – proinflamatory response (bioassays - rat alveolar macrophages) higher for indoor particles than outdoor particles (**14 paired samples in Boston area**)
- Oeder et al., 2012 indoor PM10 from **school** compared with outdoor PM10 induced more inflammatory and allergic reactions, and accelerated blood coagulations
- Skovmand et al., 2017 **candle light** particles caused higher inflammation and cytotoxicity in the mice lungs (after intratracheal instillation) than diesel exhaust particles
- Wierzbicka et al. (in prep.) particles collected indoors caused higher toxicity (acute phase response/inflammation) in mice (after intratracheal instillation) than particles from outdoors (**16 occupied residences in Sweden**)

Main messages

- Indoors we are exposed not only to particles of outdoor origin
- Several indoor sources contribute to high particle loads
- Energy renovations increase influence of indoor sources of particle
- Kitchen hoods if efficient and properly incorporated in ventilation system can be an effective tool to remove particles from indoors

Four principles for achieving good indoor air quality

- Minimize indoor emissions
- Keep it dry
- Ventilate well
- Protect against outdoor pollution

Nazaroff W. W. 2013., Four principles for achieving good indoor air quality. Indoor Air 2013; 23: 353–356

Contact: aneta.wierzbicka@design.lth.se

More info about indoor environment quality:

Centre for Healthy Indoor Environments https://www.chie.lth.se/

SWESIAQ https://swesiaq.se/

SWESIAQ

SWESIAQ
Swedish Chapter of International Society of Indoor Air Quality and Climate