



# Indoor particles – characteristics and toxicity

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**We are exposed to air pollutants  
mainly inside the buildings**

# How much time do we spend indoors?

Average time spend daily at given locations (%)

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

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

# Indoor sources of airborne particles - examples

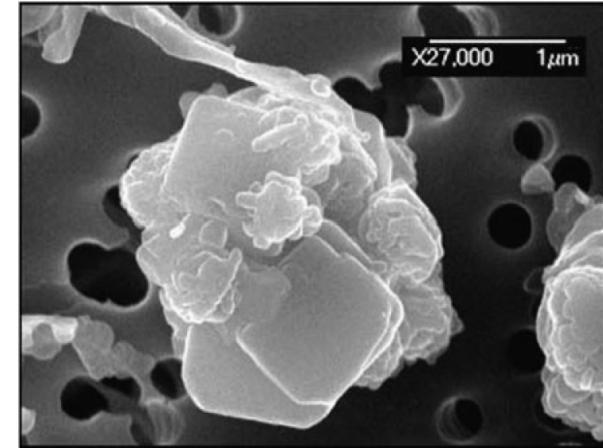


New products

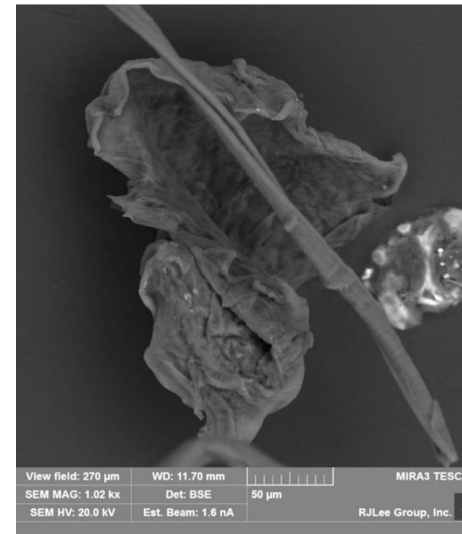
# Sources of particles indoors

## People "personal cloud"

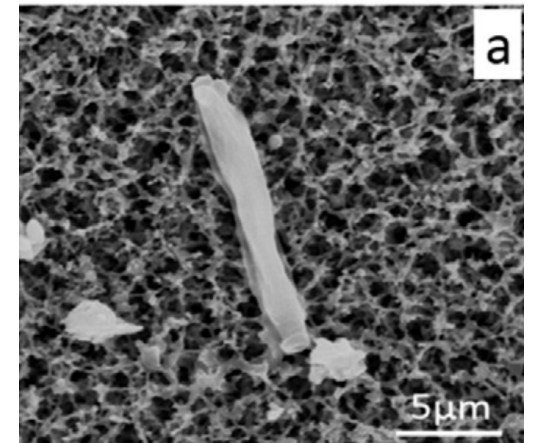
- Skin flakes
  - Fibers
  - Washing powder residues
  - Personal care products
    - precursors for particles formation
  - Bioeffluents and exhaled particles
- 
- Interiors
  - Microplastics



Gudmundsson et al 2007

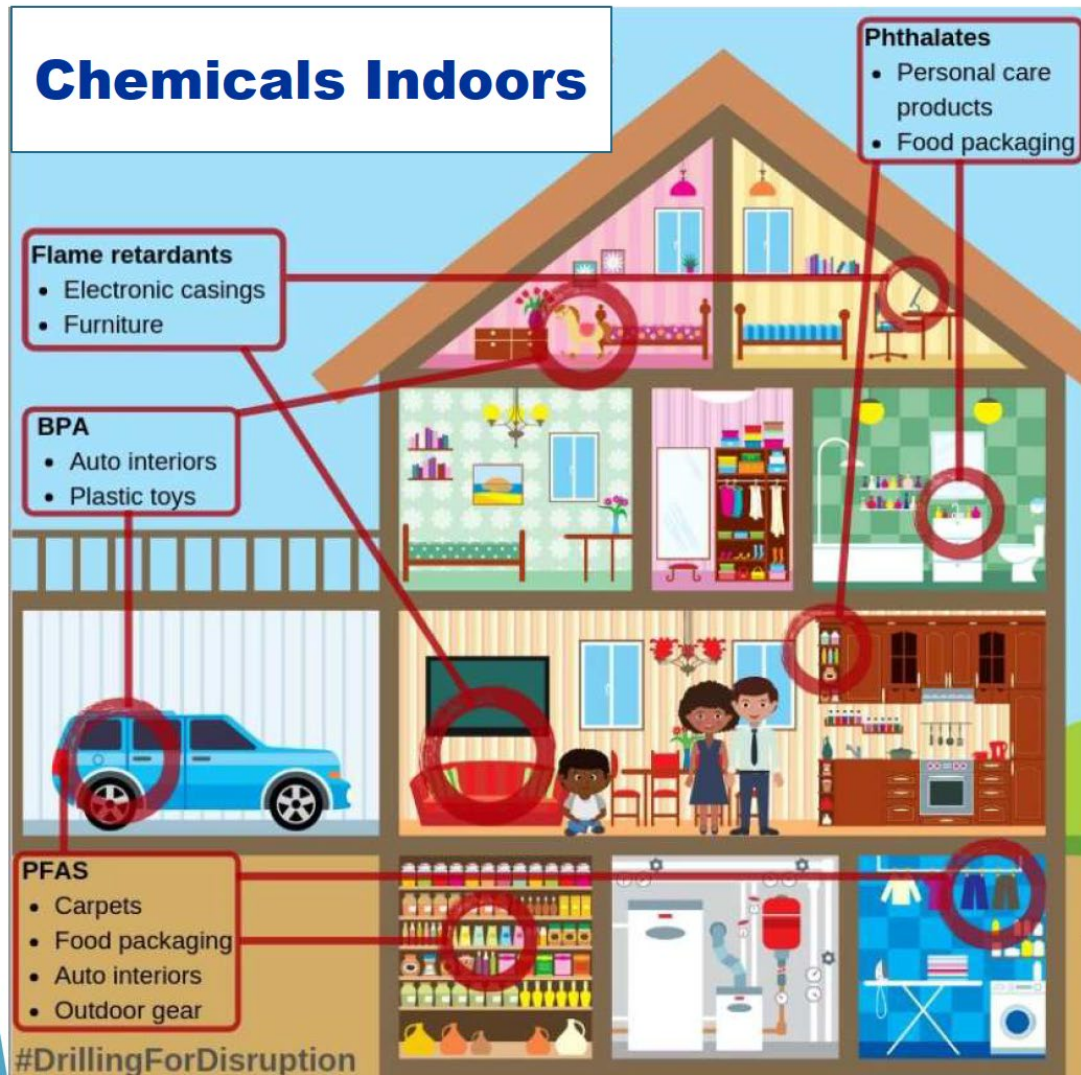


Meyer, 2019



Li et al 2020

# Gas phase pollutants indoors



[www.endocrinedisruption.org](http://www.endocrinedisruption.org), Nov 2020

**VOC:** Volatile Organic Compounds,  
Examples: aldehydes (formaldehyde, acetaldehyde, acrolein), toluene, benzene, terpenes

**Phthalates**, example: Diethyl phthalate (DEP)

**BPA:** Bisphenol A

**PBDEs:** polybrominated diphenyl ethers (flame retardants)

**PFAS:** per- and polyfluorinated alkyl substances

**PCB:** polychlorinated biphenyls

**Radon**

# Airborne particles in indoor environments

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

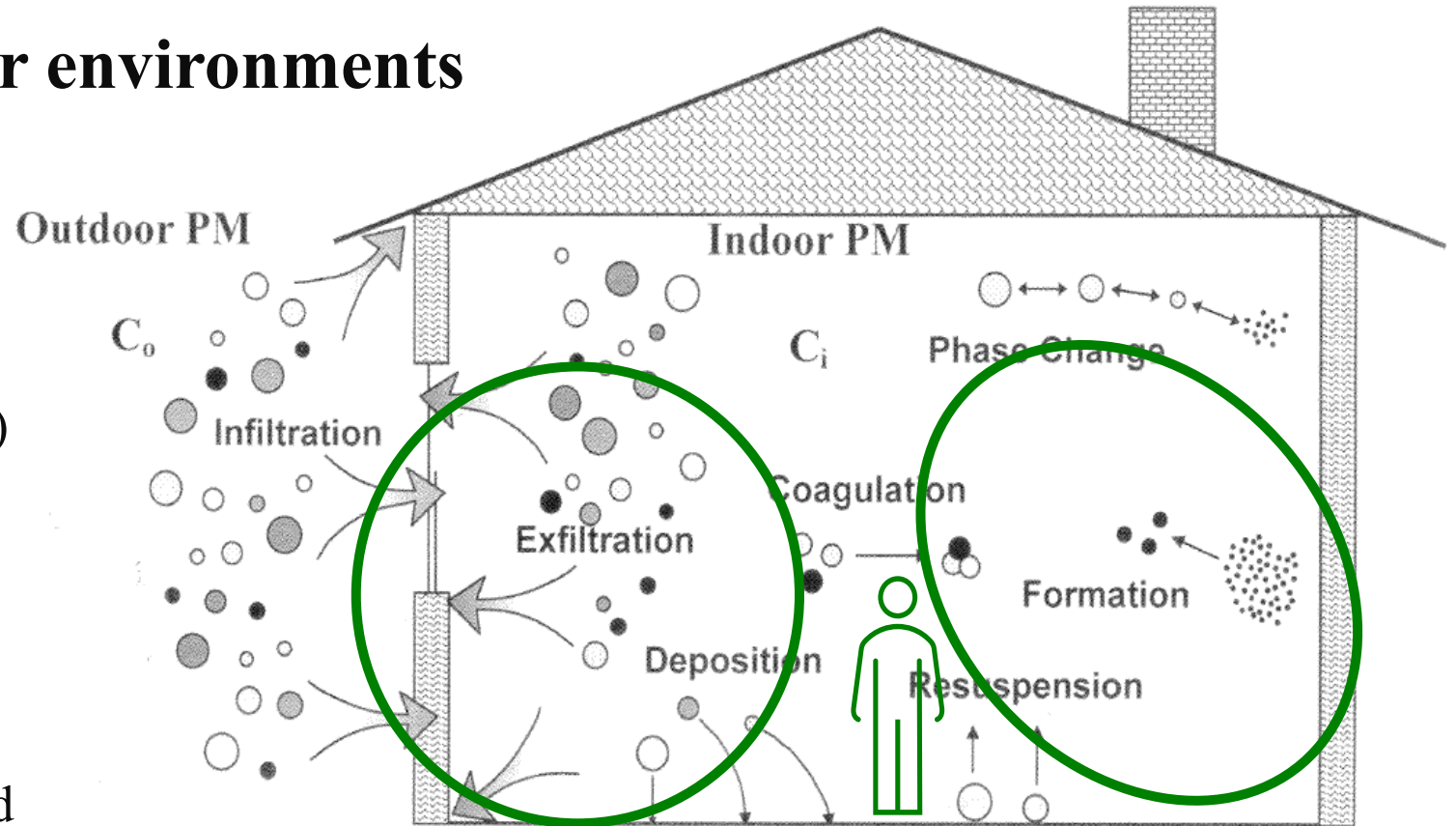
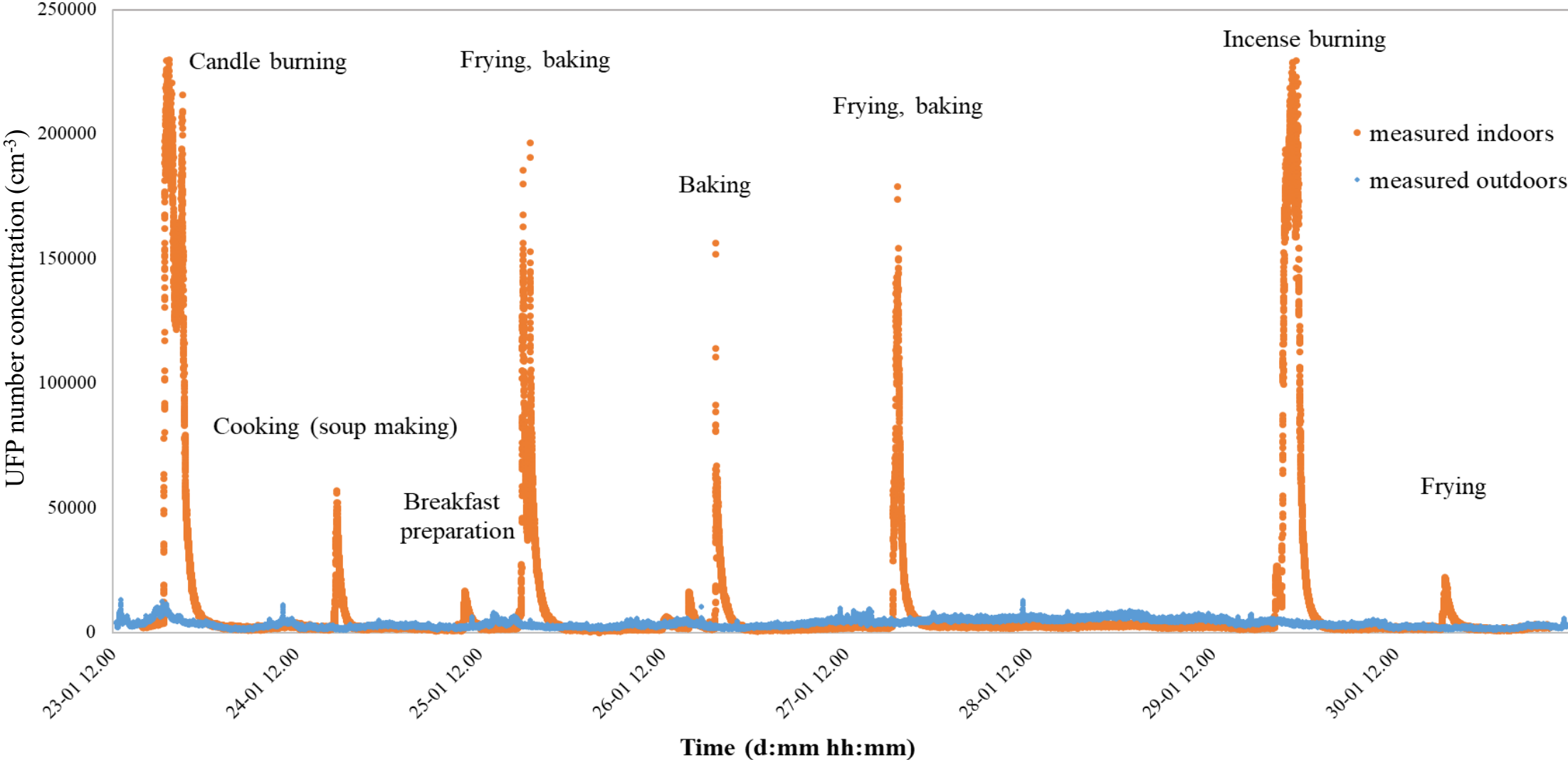


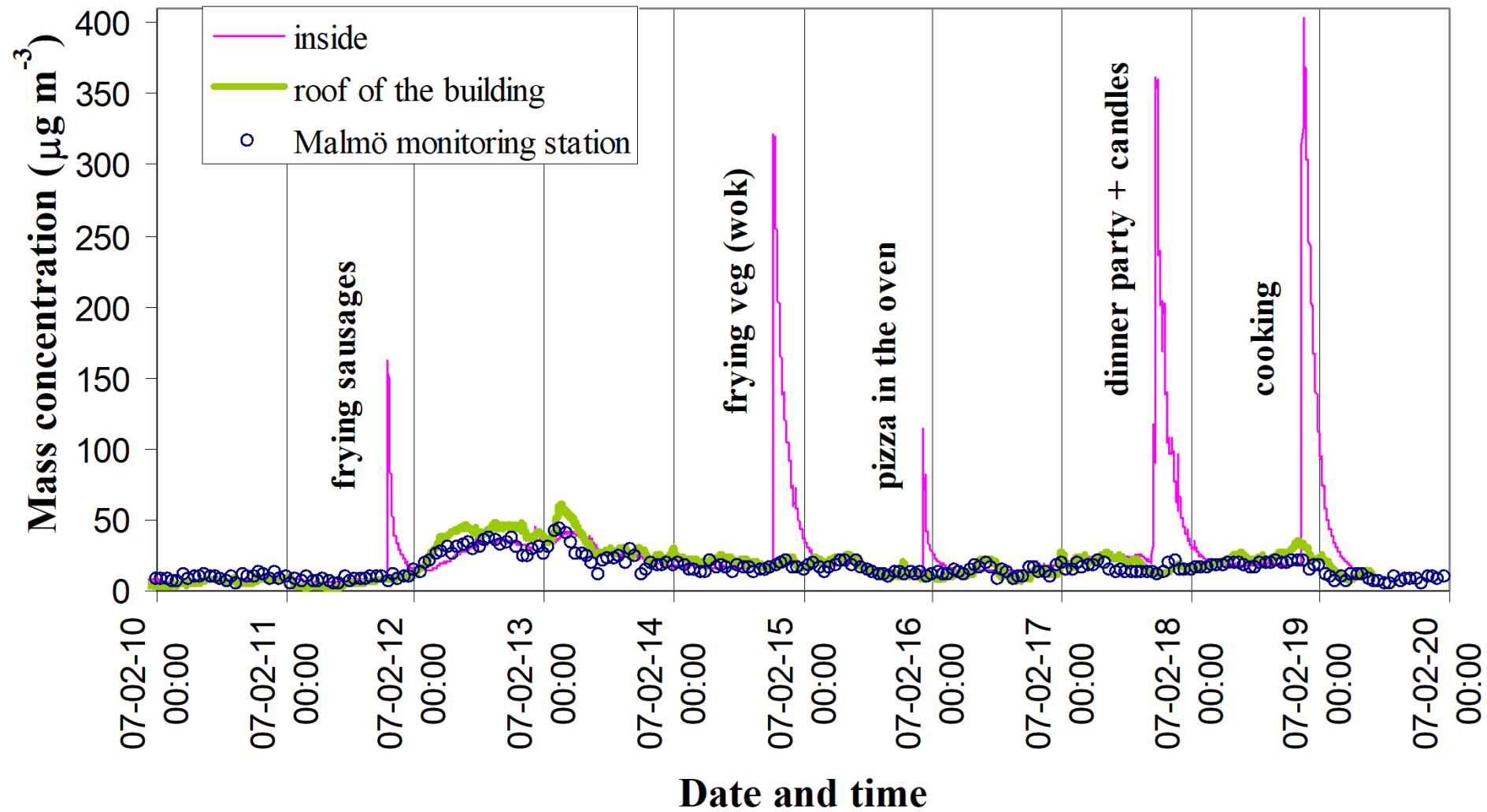
Figure 3. Schematic of particle transport, transformation, and removal processes in the indoor environment.

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

# UFP number concentrations – indoors and outdoors



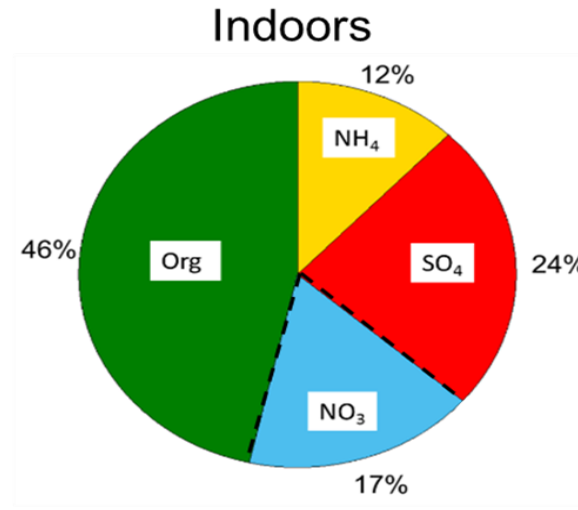
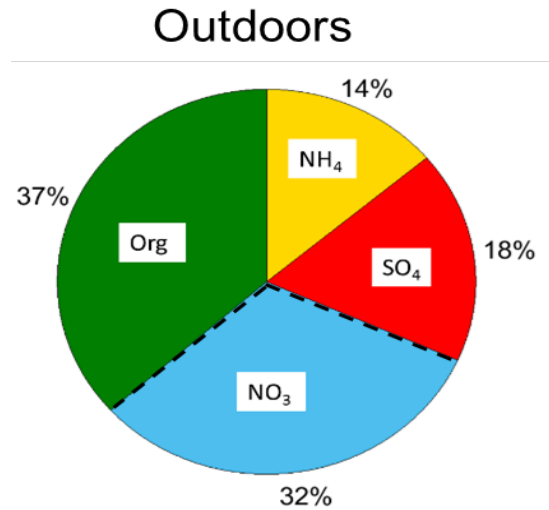
# PM<sub>2.5</sub> mass concentration- indoors and outdoors





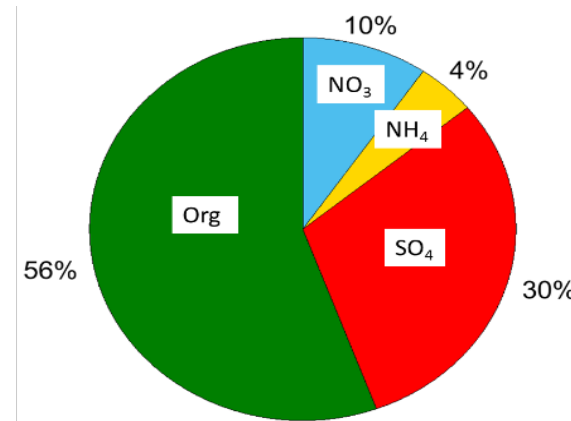
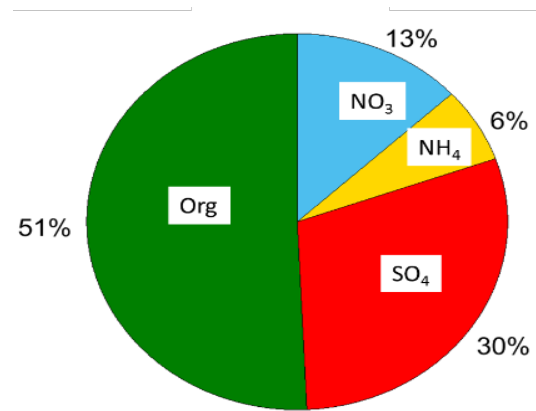
# Non-occupancy: seasonal differences in chemical composition

Winter



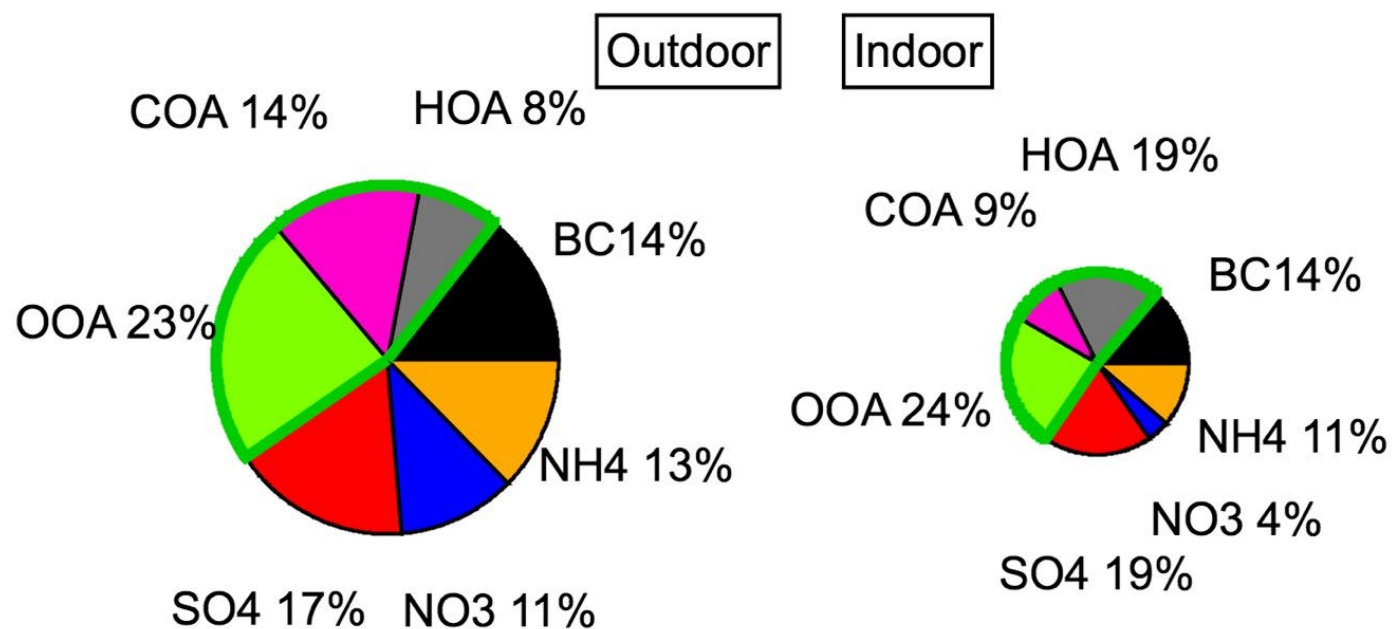
- reduced share of NO<sub>3</sub><sup>-</sup> indoors

Summer



- very similar proportions of chemical species indoors and outdoors

# Non-occupancy



Identified on the basis of PMF:

HOA- hydrocarbonlike organics

COA - cooking organics

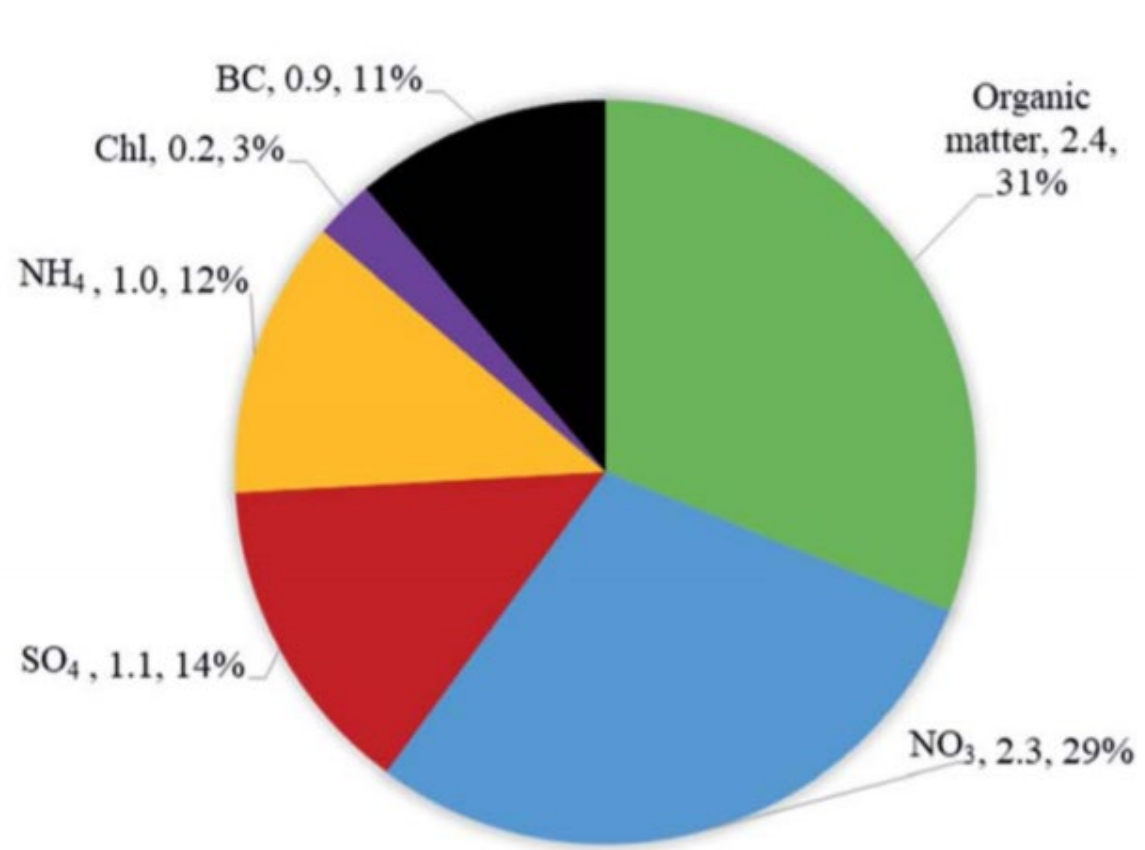
OOA – oxygenated organics

Johnson, A. M.; Waring, M. S.; Decarlo, P. F. Real-time transformation of outdoor aerosol components upon transport indoors measured with aerosol mass spectrometry. *Indoor air*, 2017, 27.1: 230-240.

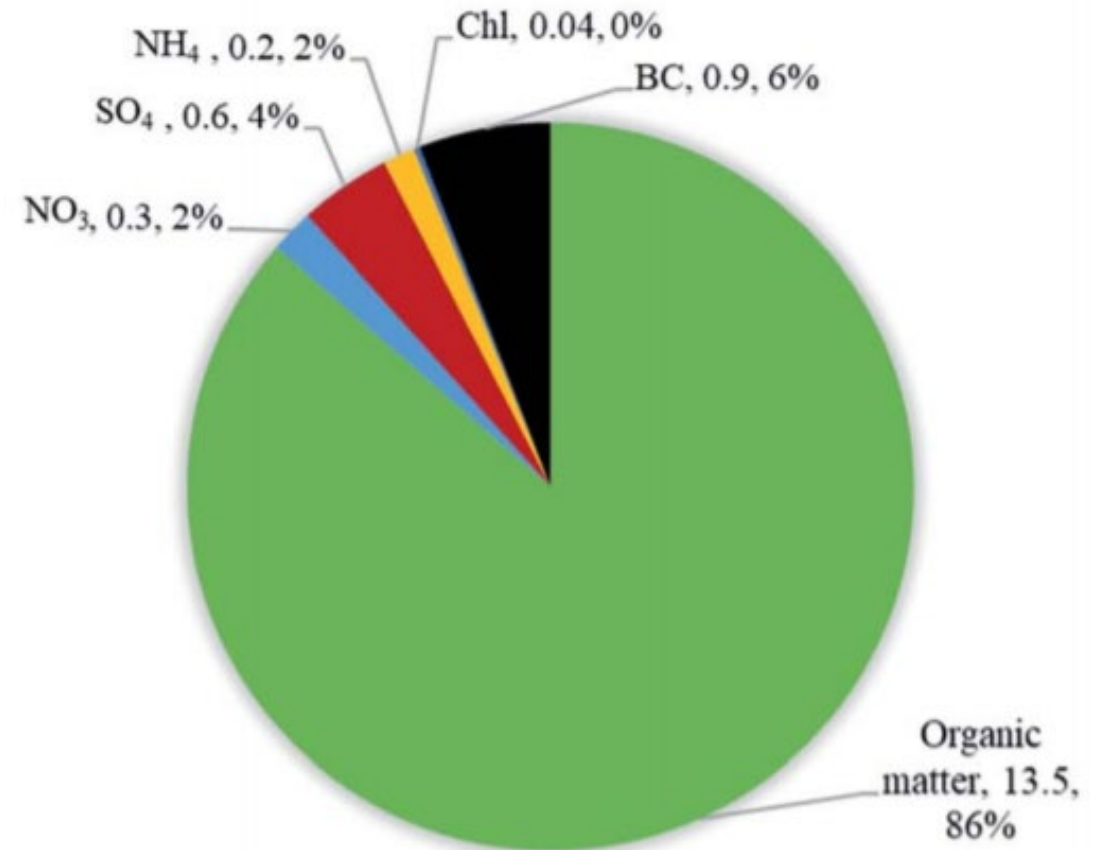
Parametrisation of the transformations dependence on differences between outdoor and indoor T and RH (also done by Avery et al 2019)

# Occupancy

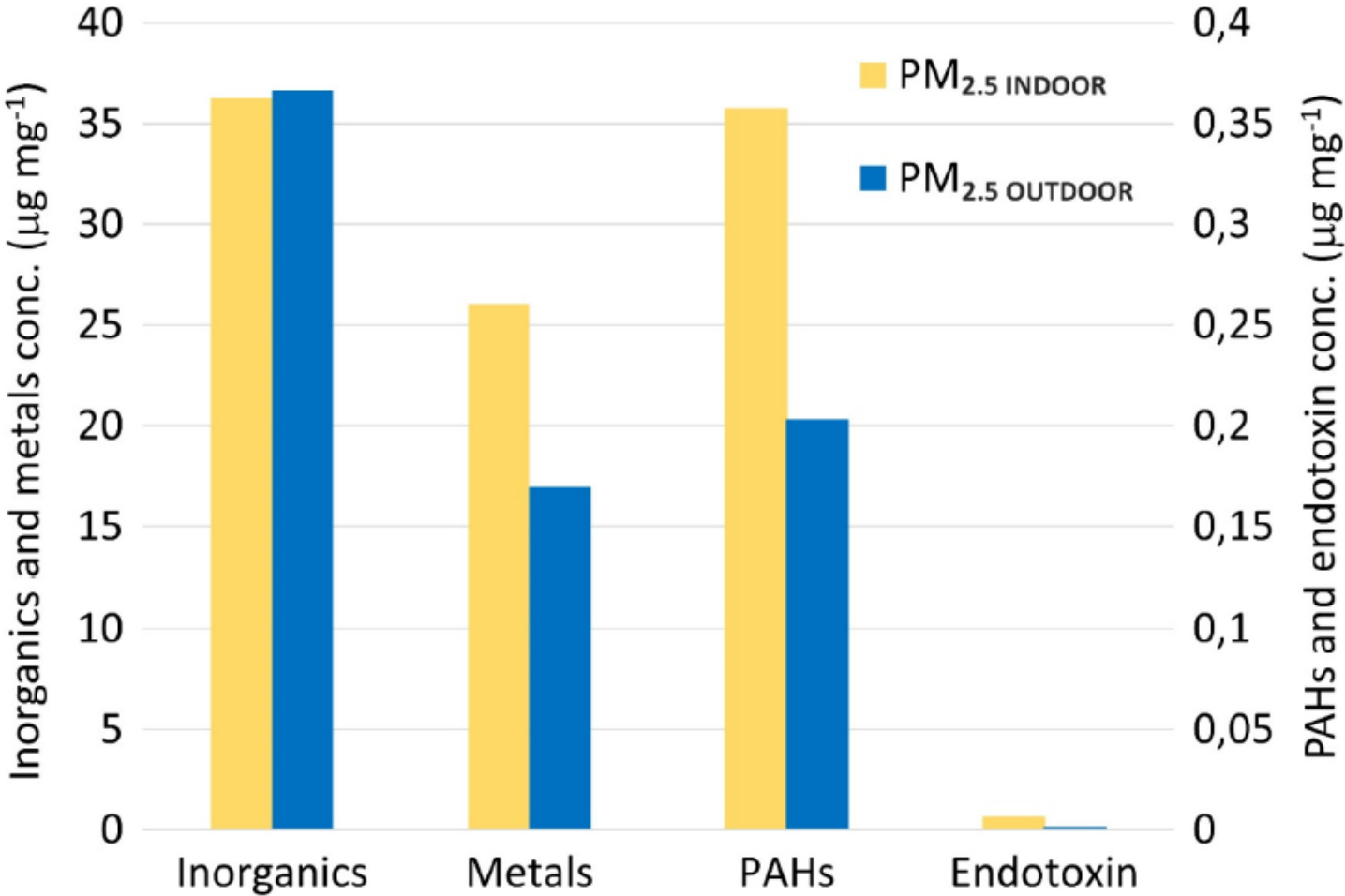
**Outdoors 7.0  $\mu\text{g m}^{-3}$**



**Indoors 15.0  $\mu\text{g m}^{-3}$**



# Chemical composition – 16 Swedish homes



From Wierzbicka et al. 2022

**Toxicity ?**

## Facts / puzzle

- Epidemiological studies – strong correlation between particle mass concentration and health effects
- Tox studies – strong evidence for UFP toxicity
- In indoor environments powerful indoor sources contribute to high UFP number concentrations....
- ROS reported to be driven by organic aerosols (and BC) outdoors
- Organics dominate chemical composition of particles found in homes
- We spend majority of the time indoors....

In epidemiological studies assessing health effects of exposure to airborne particles, indoor environments are considered as places where people are exposed to particles of outdoor origin.

Can we do better?

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

Research/scientific evidence is needed:

- Toxicity of particles collected indoors

→ Through tox studies

→ ROS/OP (toxicity indicator) assessment indoors (generally not known, only few studies exist: tobacco smoke, measurements in homes (Khurshid et al, 2016; 2014), e-cigarettes (Son et al 2019)), incense & ETS (Niu et al 2022), Wierzbicka et al (in prep)

- Provide enough indoor exposure data (population-relevant scale) to enable epidemiological studies on health effects

→ Through measurements in large amount of indoor environments (portable, simpler instruments, sensors)

→ Through modelling



Source: drwritings.com



Sources: www.psyllife.eu

# 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 – proinflammatory 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. 2022 particles collected indoors caused higher toxicity (acute phase response/inflammation) in mice (after intratracheal instillation) than particles from outdoors (16 occupied residences in Sweden)

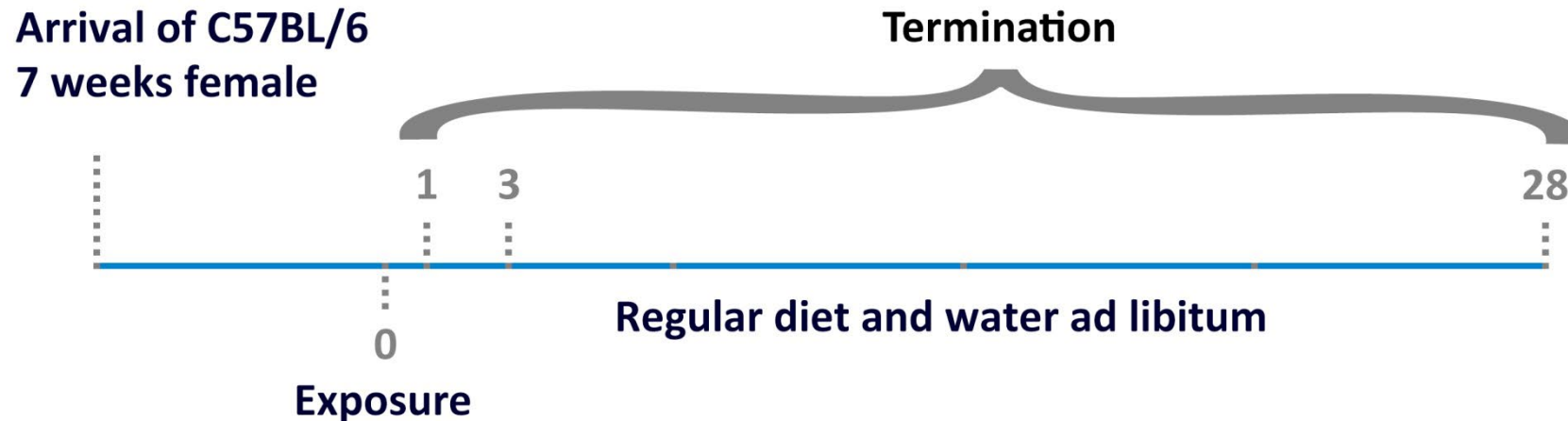


# Toxicological testing in mice

Female C57BL (N=162 mice, in each group 6 mice per dose)

Mice received a single intratracheal instillation of 18, 54 and 162  $\mu\text{g}$  of the pooled particle samples. Suspended in NanoPure water with 0.1% Tween80

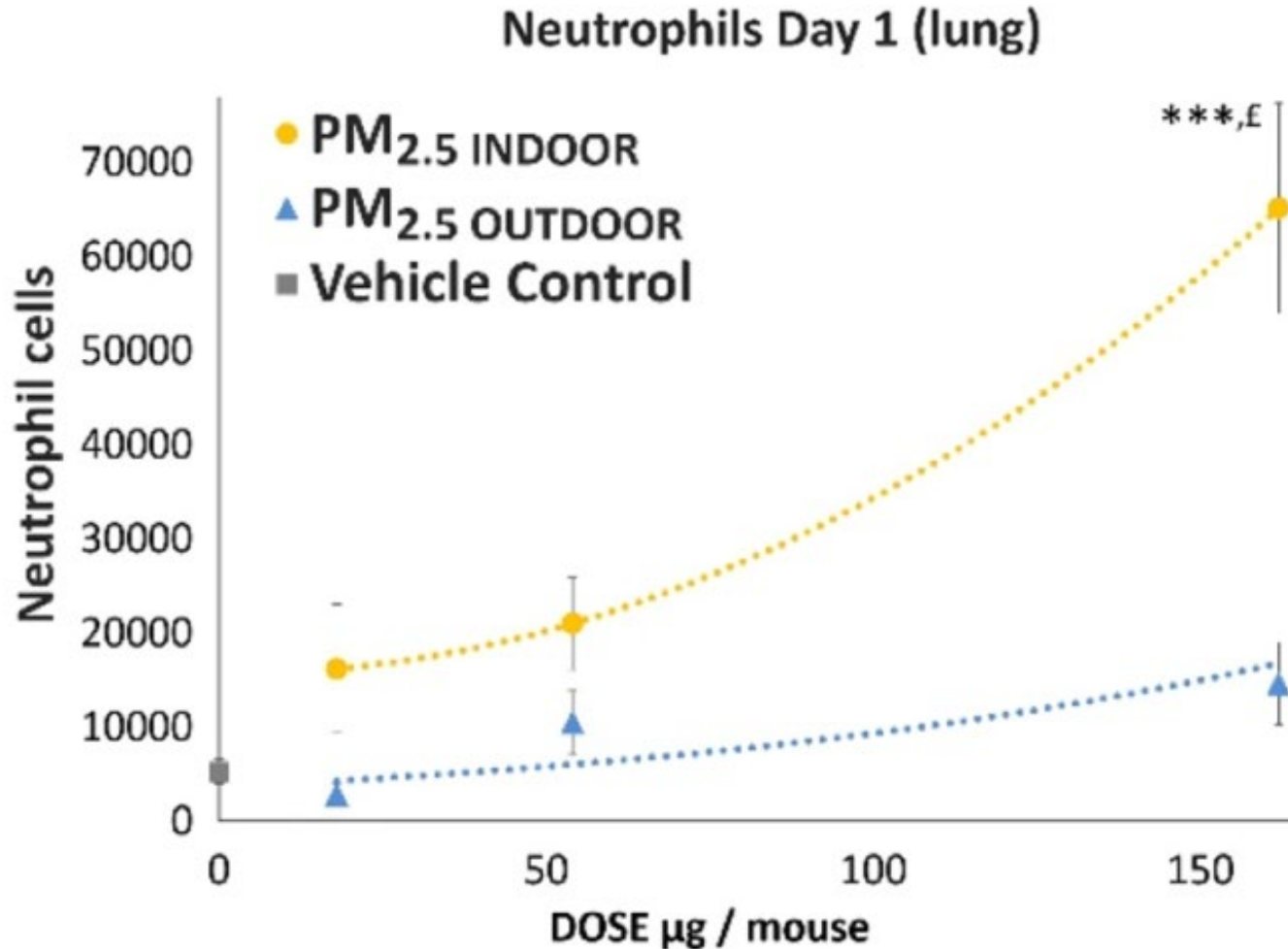
Carbon Black Printex 90/XE-2B was used as a positive control



Lung inflammation, genotoxicity, and acute-phase response in lung were evaluated 1, 3 and 28 days after intratracheal instillation.

# Observed effects

In bronchoalveolar lavage (BAL) after a single intratracheal instillation of 18, 54 and 162  $\mu\text{g}$  of particles



\*\*\* Statistically significant increase compared to control mice at the 0.001 level.

£ Statistically significant increase compared to PM<sub>2.5</sub> OUTDOOR exposed mice at the 0.05 level

Printex 90 at 162  $\mu\text{g}$  dose:  
After 1 day: 98490 Neutrophils cells

## Conclusions

- Higher concentrations of metals, PAHs and endotoxins were observed indoors than outdoors
- PM<sub>2.5</sub> indoors caused significantly higher lung inflammation and lung acute- phase response 1 day post-exposure compared to PM<sub>2.5</sub> outdoors
- None of the tested materials caused genotoxicity.
- PM<sub>2.5</sub> indoors displayed higher relative toxicity than PM<sub>2.5</sub> outdoors under the studied conditions: wintertime with reduced air exchange rates, high influence of indoor sources, and relatively low outdoor concentrations
- Reducing exposure indoors requires reduction of both infiltration from outdoors and indoor-generated particles

# Kitchen hoods

- Their efficiency varies between 30% (!) and 98%
- (?) Development focused on aesthetically pleasing design?
- Not integrated/automated with stove and oven use, require active switching on by the user
- Flexible oven placement – not close to kitchen hood
- Too loud – users choose not to use it
- 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)



**What can we do to decrease our exposure to particles indoors?**

# How to achieving good indoor air quality

1. Minimize indoor emissions
2. Keep it dry
3. Ventilate well
4. Protect against outdoor pollution

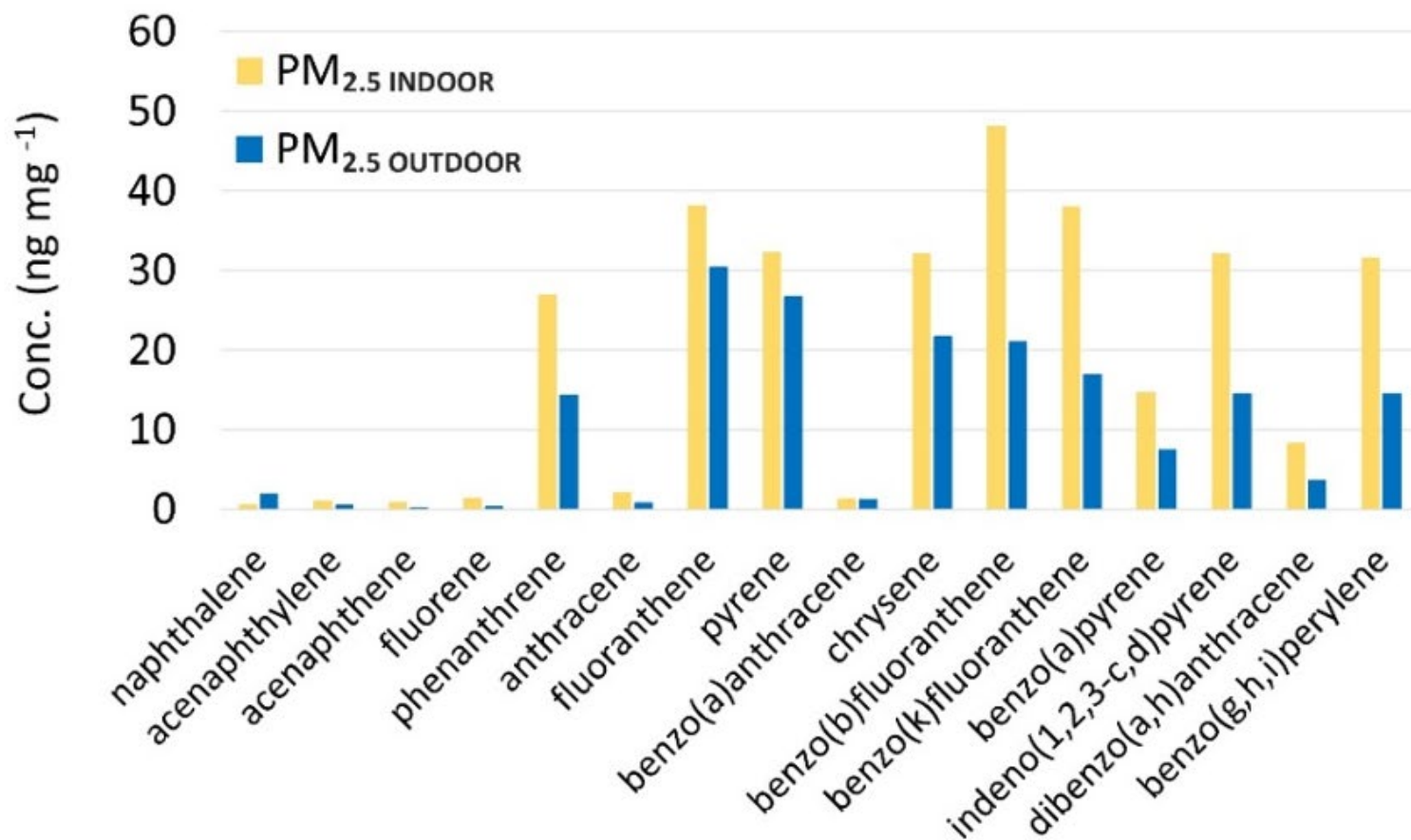
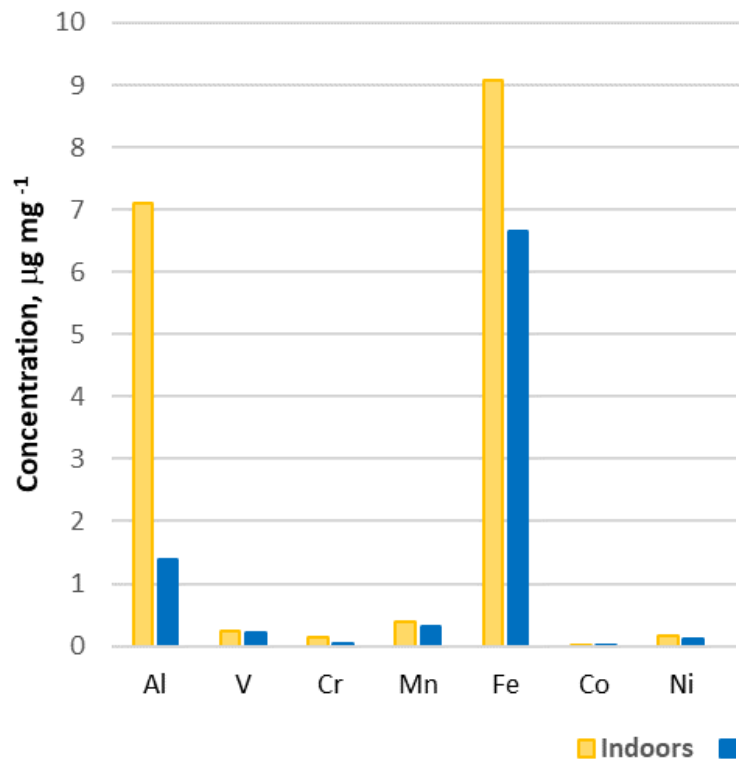
Nazaroff W. W. 2013., Four principles for achieving good indoor air quality Indoor Air 2013; 23: 353–356



## Aneta's tips:

- Do not burn candles, incense, do not use decorative tabletop fire-places
- Use kitchen hoods
- Do not use ozone generators – these are not air cleaners!
- Make sure ventilation works as it should

# Chemical composition – 16 Swedish homes



From Wierzbicka et al. 2022

# **The differences between indoor and outdoor environments:**

- Volumes of confined indoor spaces (influencing dilution and dispersion)
- Surface to volume ratio (deposition)
- Residence time (minutes to hours)
- Light characteristics
- Temperature and humidity profiles

# ROS - DCFH probe

