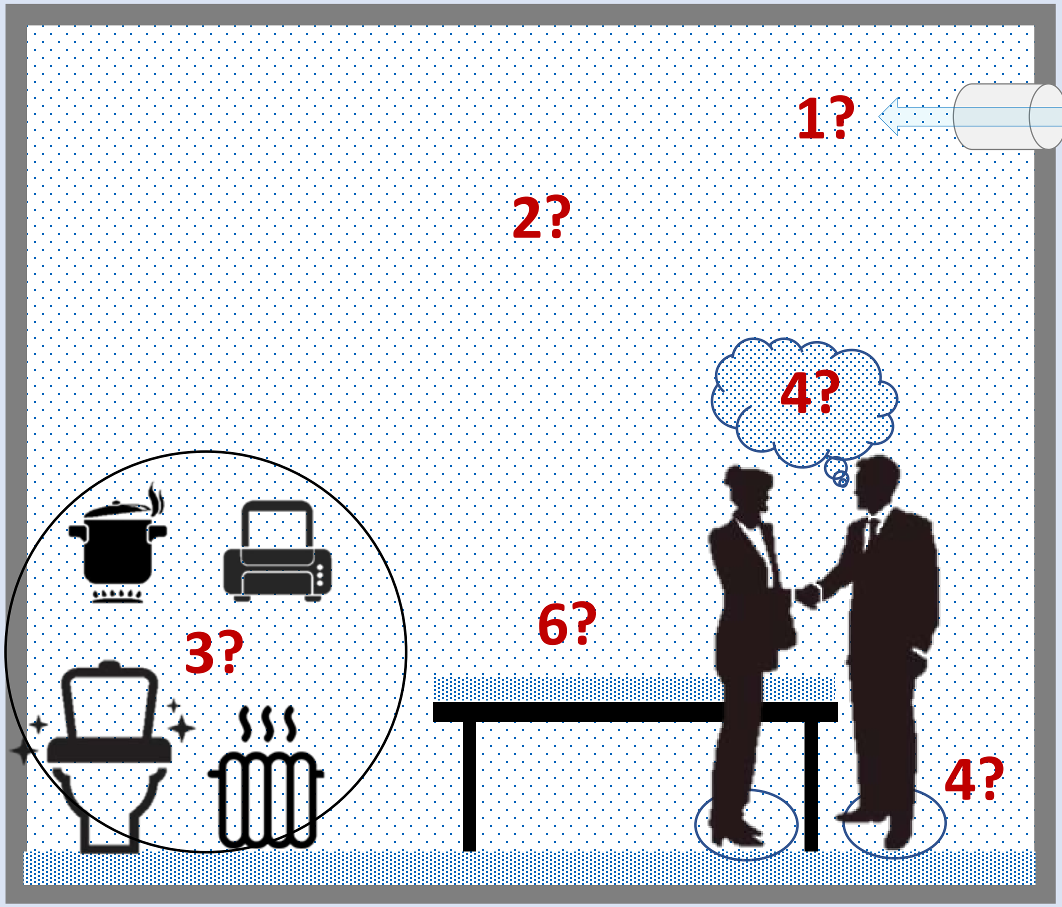
Where is the **bulk** of **floatable pollutants (= inhalable)** in the built environment?
Where do they come from?

The bulk of indoor pollution is generated by resuspension and indoor emissions



1. Outdoor Air
2. Room Air
3. Device Emission
4. Occupant-Emission

Pico- gram pg/m³

Micro- gram mg/m³

pollutant – mass concentrations

$10^{-6} g/m^3$ << $10^{-3} g/m^3$

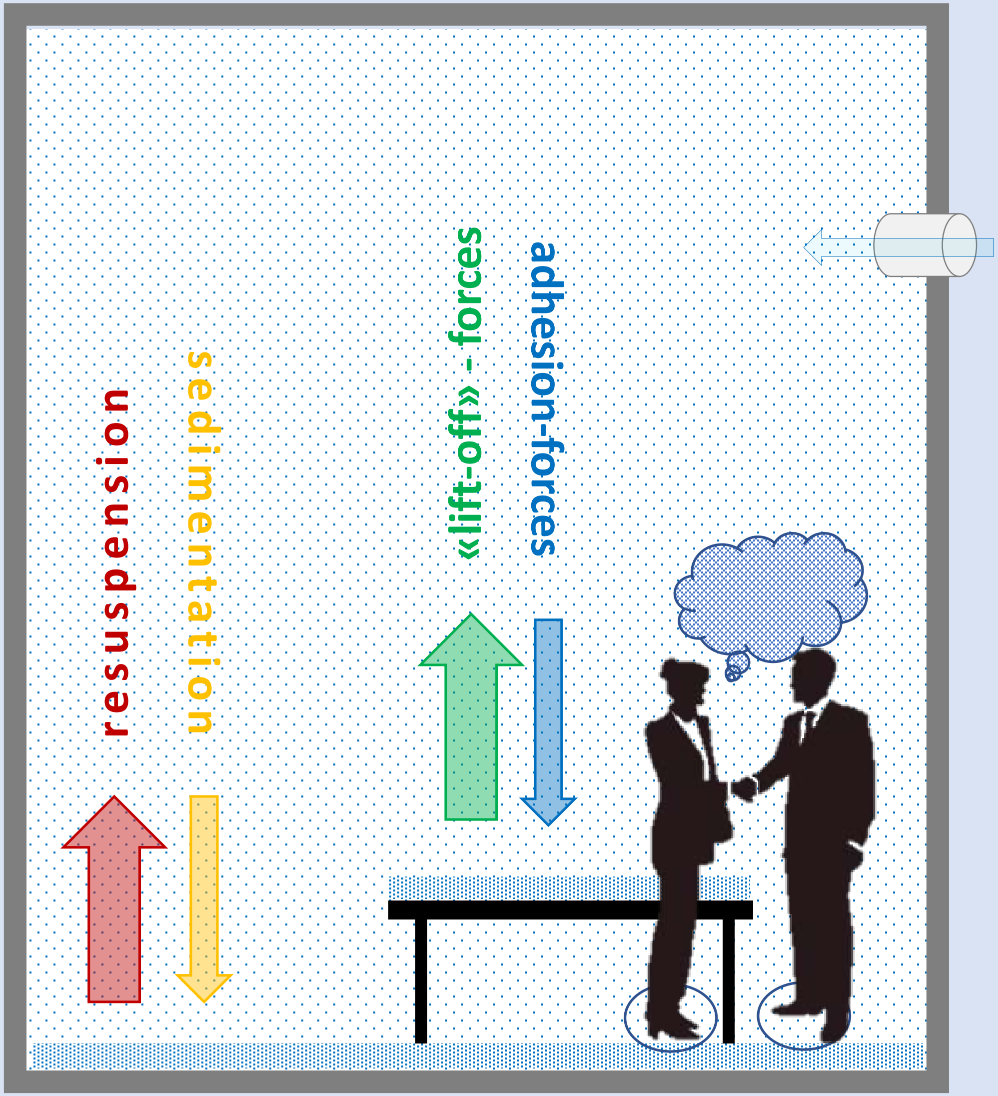
5. incorporation by user
6. settled pollutants on surfaces

Milli- gram mg/m²

Pulmonary exposure is determined by

①occupants activities (→ resuspension of accumulated bulk of floatable pollutants on surfaces)

②emissions of occupants and other sources in the room



occupants activities + emissions

convection

triggered by occupants

thermal or pressure induced

ventilation induced

adhesion forces

surface materials

water adhesion

electrostatic adhesion

In view of airborne pollution **humidity**, **surface material properties** and **cleaning efficiency** are crucial

Humidity around and above 50 % **reduces resuspension** and increases **cleaning efficiency** for settled air pollutants, including microbes and allergens

Manufacturing industry protects workers from dangerous airborne pollutants (drilling, grinding, milling and sawing) by humidification (diminishes as well bad odours e.g. in waste industry!)

Why not reduce invisible indoor pollutants in offices, residential homes and hospitals by proper humidification ?

Instead of blaming «increased dust load» for «wrong perception» of dryness!

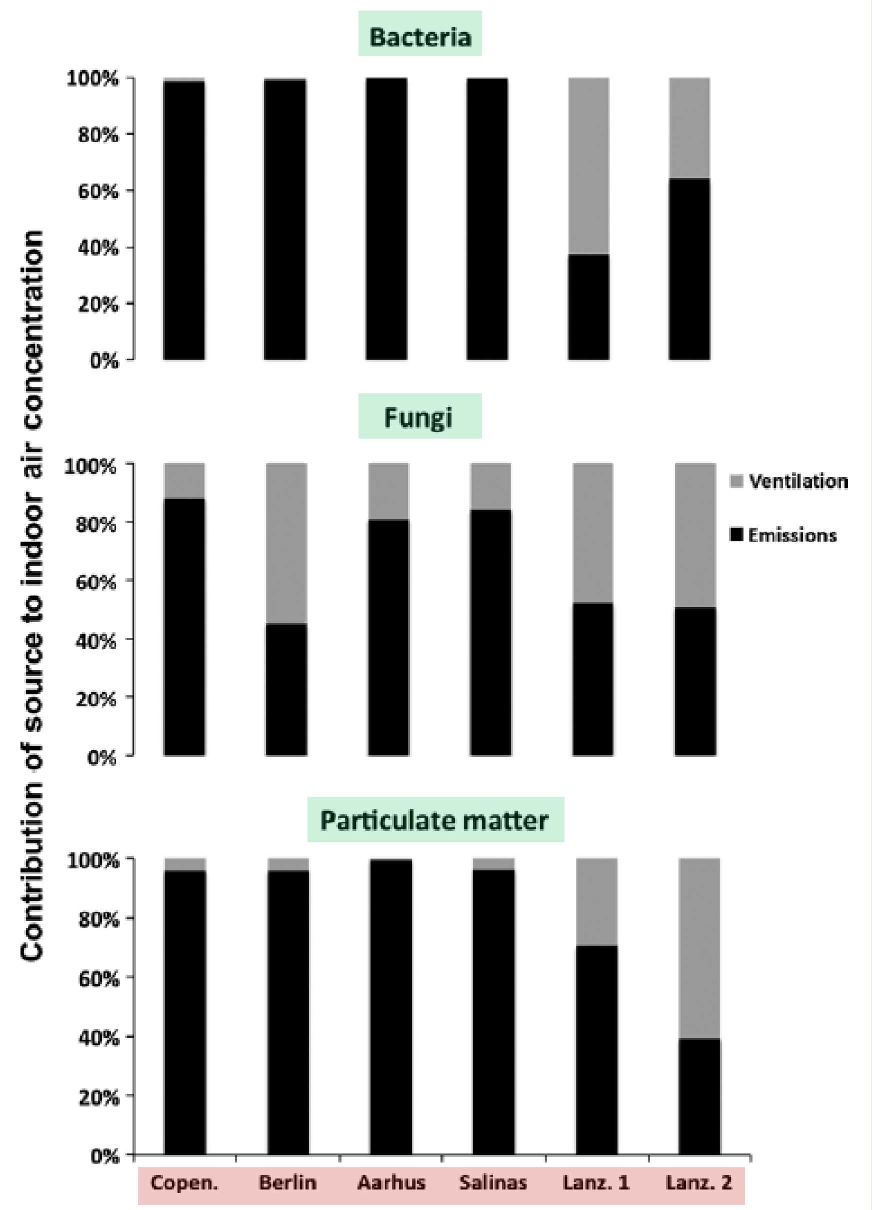


Fig. 8 Comparison of the relative contributions of outdoor sources (QC_{out}) vs. occupancy-associated indoor emission sources (emission rates, E) for bacteria (cells/h), fungi (spore equivalents/h), and airborne particle mass (μg/h). Data represent the sums across all particle sizes measured

The relative contribution of indoor sources [resuspension and occupants emissions] to outdoor sources is

for bacteria 83% ± 27%
for fungi 66% ± 19%
for PM mass 83% ± 24%

Hospodsky D et al, 2015, Characterizing airborne fungal and bacterial concentration and emission rates in six occupied children's classrooms, Indoor Air 2015; 25: 641–652

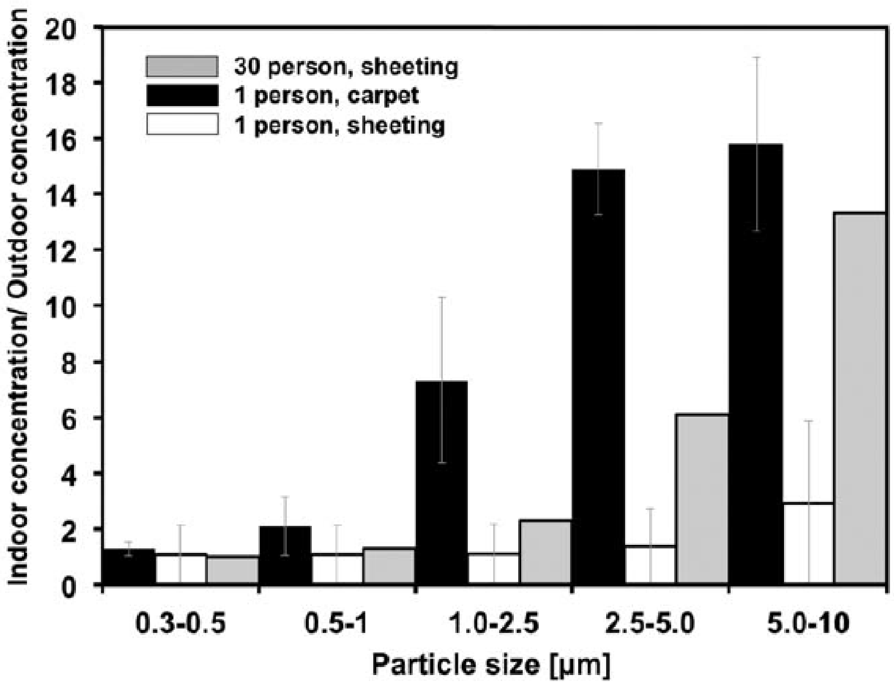


Figure 2. The influence of floor dust resuspension and particle shedding on particle number concentrations of varying optical diameter. Plotted are the ratio of occupied indoor to simultaneous outdoor particle number concentrations for five size ranges from 0.3 µm to 10 µm under the following three conditions. Black bars represent the case of 30 people sitting on a carpeted floor that is covered with plastic sheeting (to prevent resuspension of floor dust). White bars represent one person walking on a carpeted floor covered with plastic sheeting. Gray bars represent one person walking on a carpeted floor (without plastic sheeting). Error bars indicate one standard error of the mean for replicate experiments. The experiment in which 30 people were sitting on a carpeted floor covered with plastic sheeting was conducted only once.
doi:10.1371/journal.pone.0034867.g002

Human occupancy resulted in significantly elevated airborne concentrations as compared to vacant conditions:

Bacterial: 81 times
Fungal: 15 times
PM mass 9 times

Elevated airborne concentrations due to

- ***emissions from occupants***

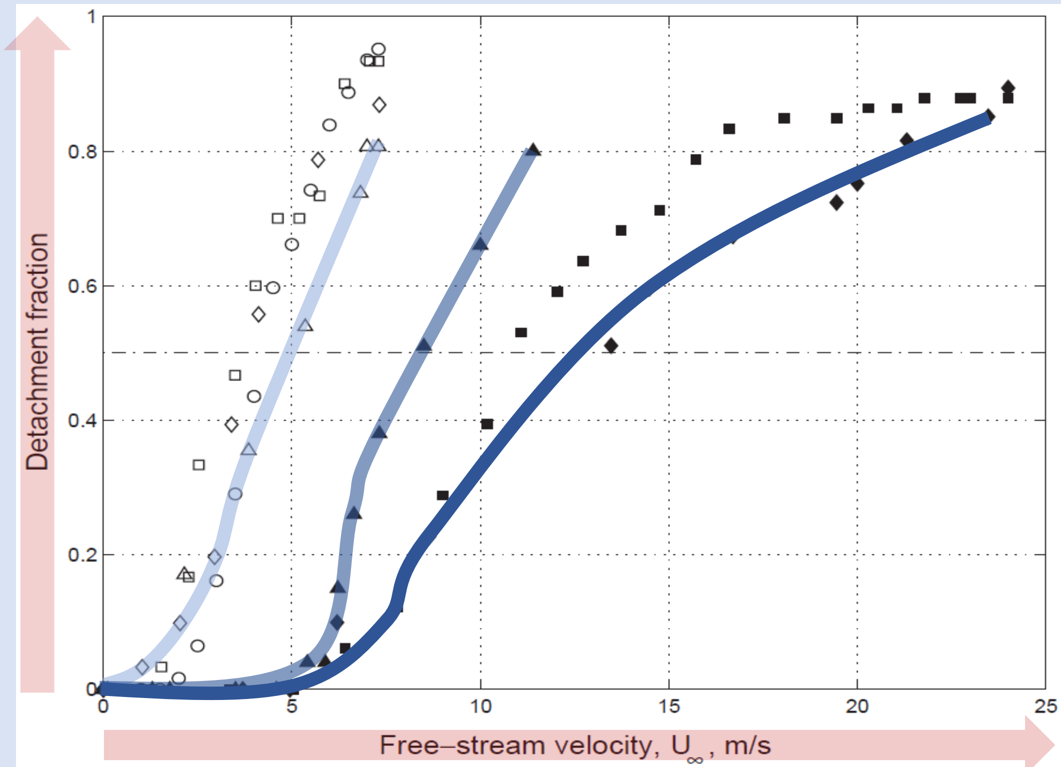
  and

- **resuspension**

Both factors were widely underestimated and almost ignored in the past !

Hospodsky D et al, 2015, Characterizing airborne fungal and bacterial concentration and emission rates in six occupied children's classrooms, Indoor Air 2015; 25: 641–652

The effect of humidity on this equilibrium state is systematically overlooked and was never investigated systematically in real buildings … although well known from experiments and everyday experience …



40 to 50% humidity is a «cut off value» for efficient adhesion of microparticles (1-100 µm) on most surfaces …

below : very low adhesion
above : rapidly increasing adhesion

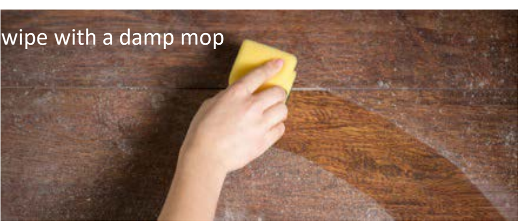
Fig. 2. Effects of the relative humidity: 18% (◇), 25% (□), 30% (○), 36% (△), 48% (▲), 61% (■) and 67% (◆). There was no residence time, the mean flow acceleration was 0.18 m/s^2, N_0 was about 0.5 particles/mm^2 and the flow was turbulent.

Ibrahim AH, 2004, Microparticle detachment from surfaces exposed to turbulent air flow- Effects of flow and particle deposition characteristics, Aerosol Science 35 (2004) 805–821

Moisture has a «sticking effect», that corresponds to our everyday perception of the adhesivity of water …

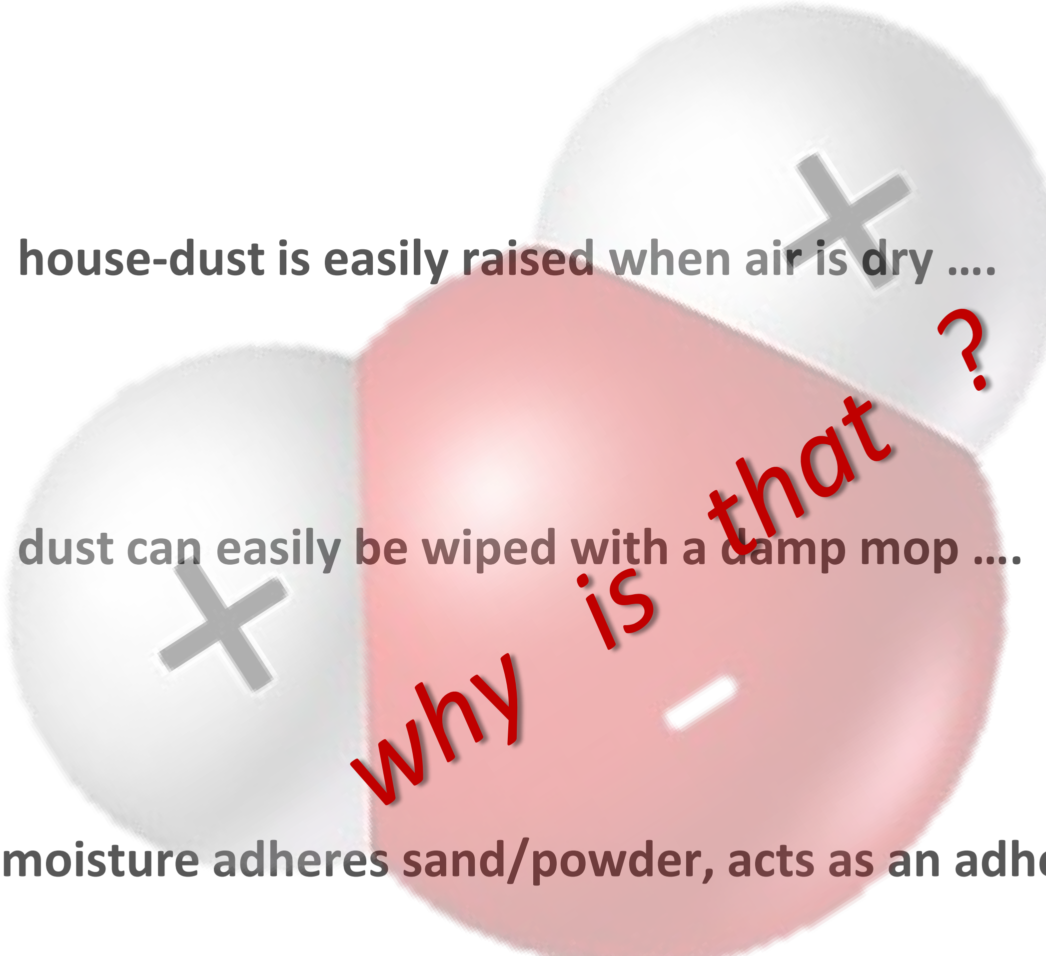
… on moistened surfaces dust and powder adhere well …

… house-dust is easily raised when air is dry ….



… dust can easily be wiped with a damp mop ….

… moisture adheres sand/powder, acts as an adhesive …



Moisture has a «sticking effect», that corresponds to our everyday perception of the adhesivity of water …

… on moistened surfaces dust and powder adhere well …

Humidity dependent adhesive forces are the strongest forces between particles and surfaces!

… house dust is easily raised when air is dry ….

«resuspension» is an important cause for increased particle numbers induced by airflows and human activities

… dust can easily be wiped with a damp mop ….

Water-covered, moistened particles adhere to each-other, clumping together as aggregates …

… moisture adheres sand/powder, acts as an adhesive …

«wet particles» adhere better to each other and to surfaces than «dry particles» …

humidity is the adhesive of particles …

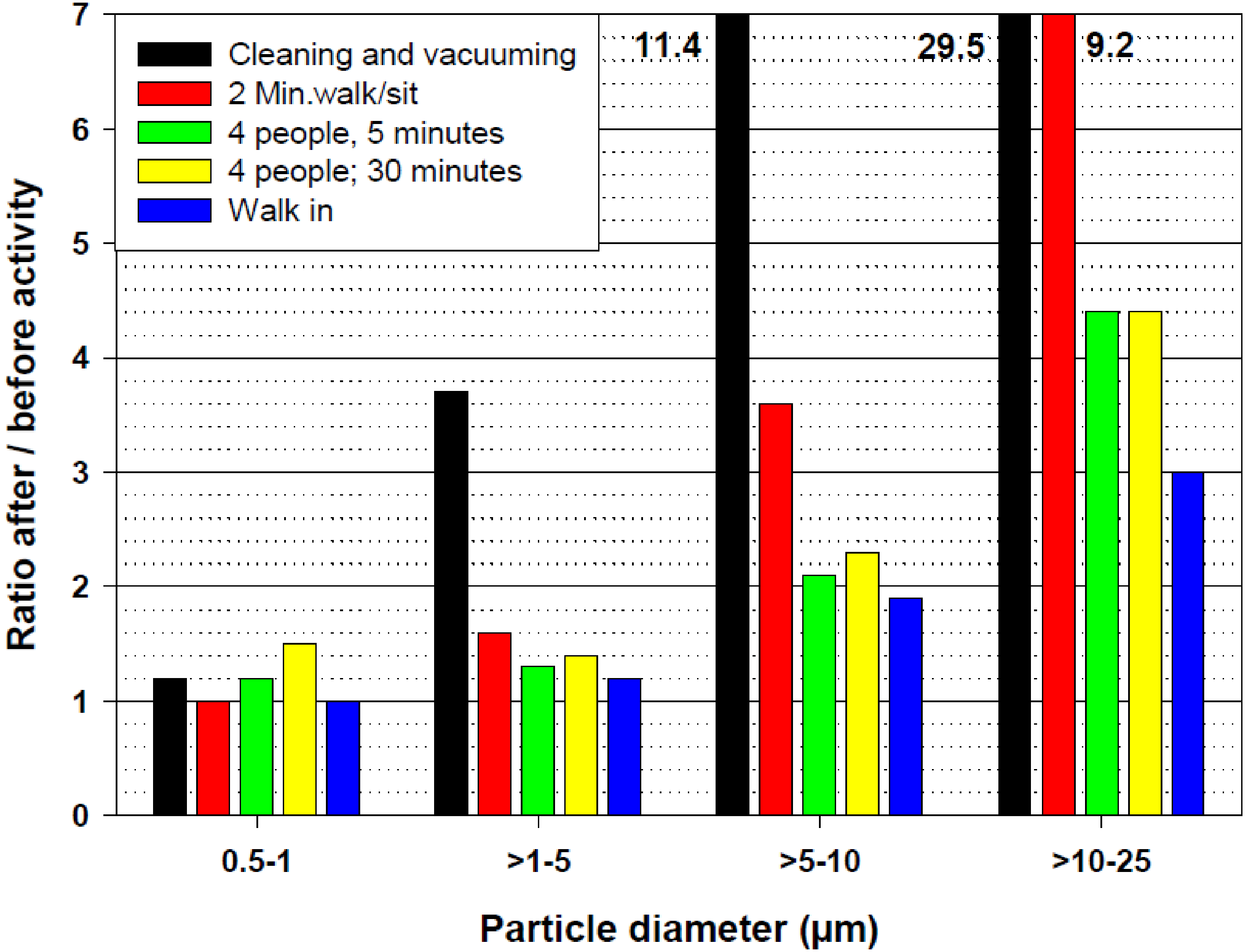
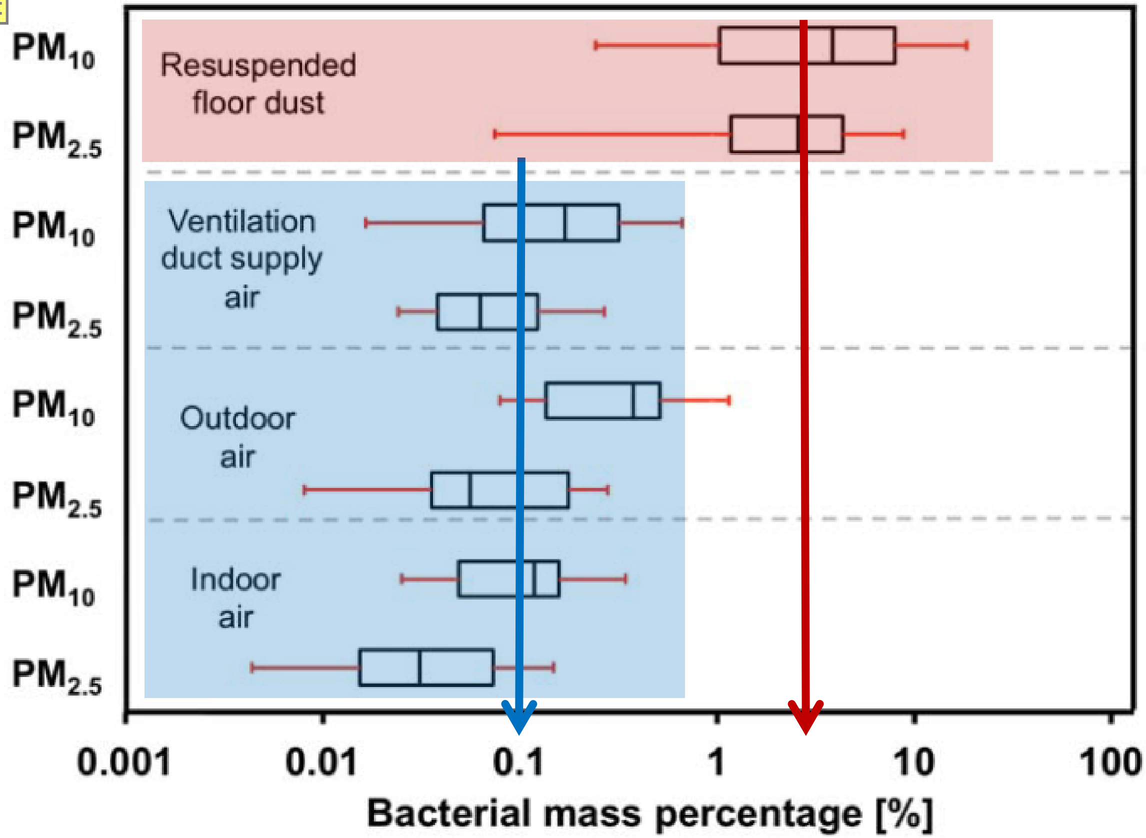


Fig. 3. The ratio of the suspended particle concentration after a resuspension activity to the indoor concentration before that activity, by particle size (modified from Thatcher & Layton, 1995)

Source: Fromme H, capter in «Air Quality – Monitoring and Modeling», pub. 2012



In re-suspended floor dust the **bacterial mass is more than 10-fold** the mass in Outdoor Air, Room Air and Supply Air …

enrichment takes place …

Figure 3. Enrichment of bacteria in airborne particulate matter and floor dust. Bacterial mass percentage (100×bacterial mass divided by total particle mass) in indoor air, outdoor air, and duct supply air samples and in the $PM_{2.5}$ and PM_{10} size fraction of resuspended floor dust samples. Mass fractions were estimated assuming an average mass of 655 fg per bacterium [25]. Box and whisker plots have the same interpretation as in Figure 1.
doi:10.1371/journal.pone.0034867.g003

Hospodsky D et al, 2012, Human Occupancy as a Source of Indoor Airborne Bacteria, PLoS ONE 7(4): e34867.

Characteristics of an optimal ventilation concept:

- targets laminar flow, avoids turbulence wherever possible
- low velocity – high volume
- flow parallels and enforces thermal convection
- avoids direction upside down!
- is demand-driven, regulated by CO_2-sensors
- main objective: «air change» not «air mixing»
- maintains slightly positive room pressure

Standard mixing ventilation concept is unfavourable!

(From the perspective of disease and infection prevention)

Displacement ventilation and natural ventilation would be Doc's Choice!