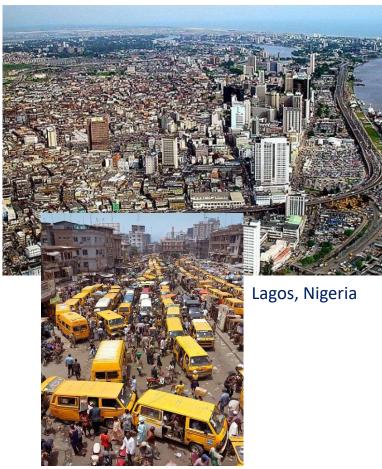# Indoor air quality:
rising issues and future challenges

Corinne Mandin

Understanding indoor air quality for healthy buildings in a net zero world

September 28th, 2022 | London
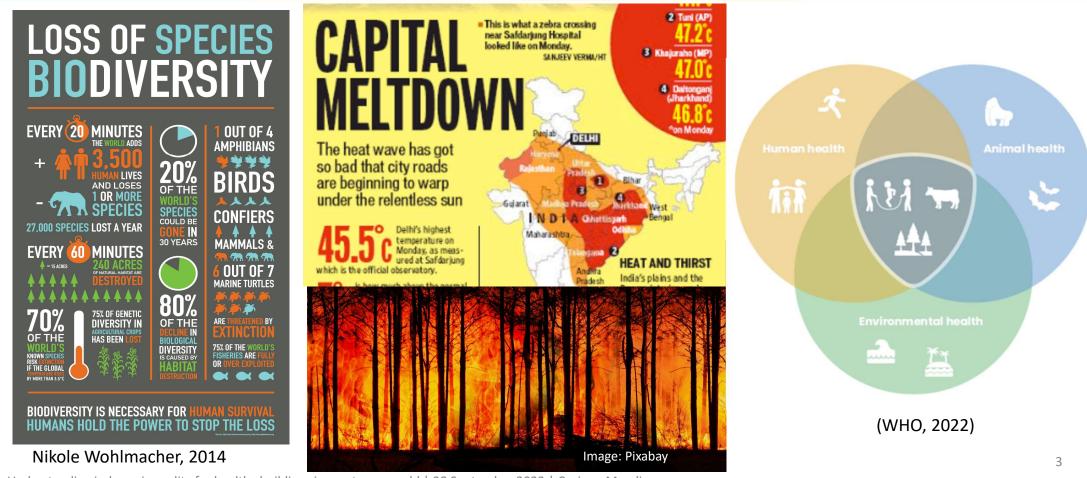
Increasing urbanization – Pollution

Lagos, Nigeria

Images: Pixabay
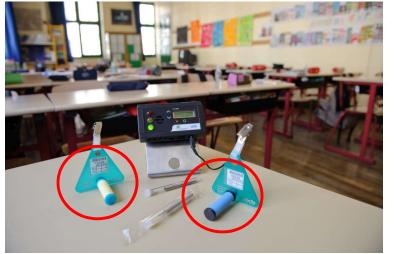
Biodiversity decline – Climate Change

Nikole Wohlmacher, 2014

Image: Pixabay

(WHO, 2022)

Challenge ❶

Make the monitoring easier
Develop on-line monitoring sensor systems

What is IAQ monitoring today?

Passive sampling

Active sampling

Real-time miniaturized sensor systems
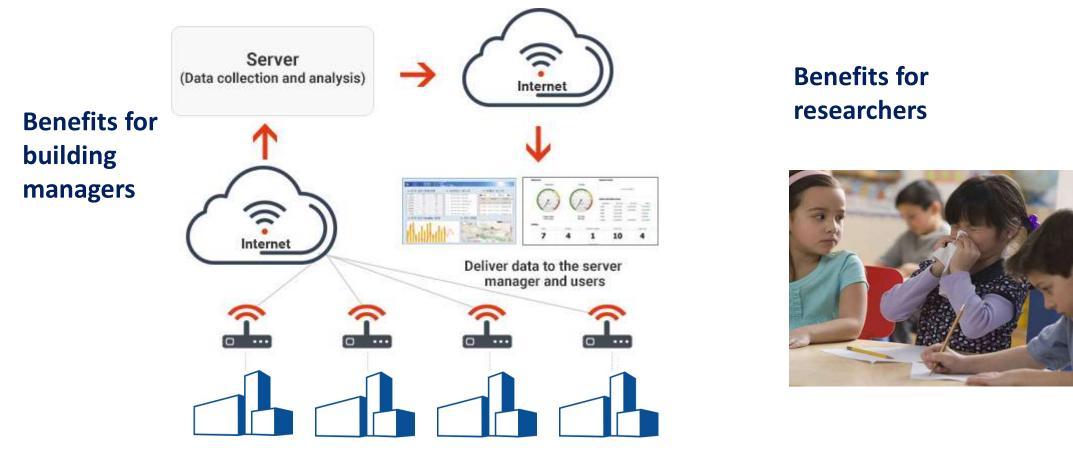
Not really new…

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Real-time miniaturized sensor systems

Benefits for building managers

Deliver data to the server manager and users

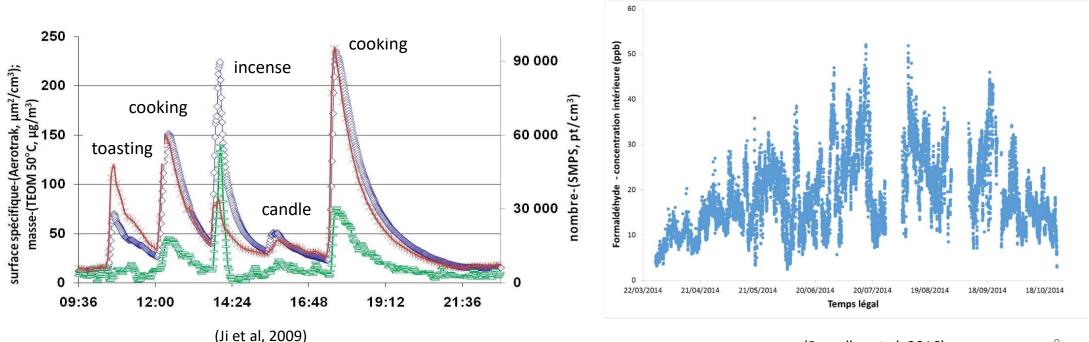**Benefits for researchers**

Temporal evolution of indoor air quality

- Source identification and their relative contributions

- Temporal variations

(Ji et al, 2009)

(Ramalho et al, 2016)

Raising awareness and making citizens actors of their IAQ

🟢 Good IAQ: windows can be kept closed

🟡 Medium IAQ: you should open the windows

🔴 Poor IAQ: open the windows!
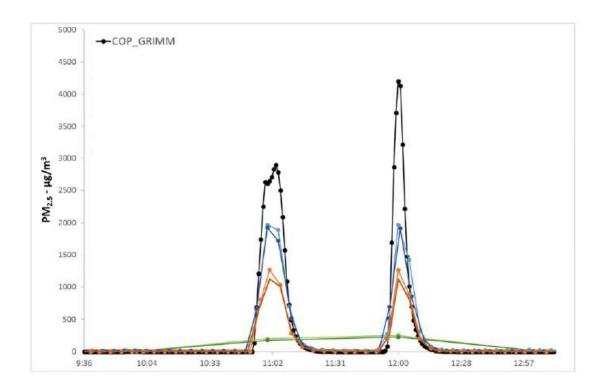
Still some limitations with IAQ sensors

Some remain expensive

Low-cost ones:

- Not all reliable

- Interferences with humidity

- Few pollutants can be measured with smart sensors

- No calibration

- Drift over time

- Etc.

$PM_{2.5}$ from incense burning at 2500 µg/m³ and 4000 µg/m³

(Ramalho et al., 2019)
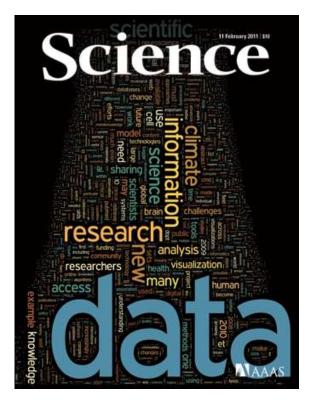
Still some limitations with IAQ sensors

CO$_2$ at 640, 1000 and 1400 ppm

(Ramalho et al., 2019)

Entering the big data era

Make the invisible visible and understandable
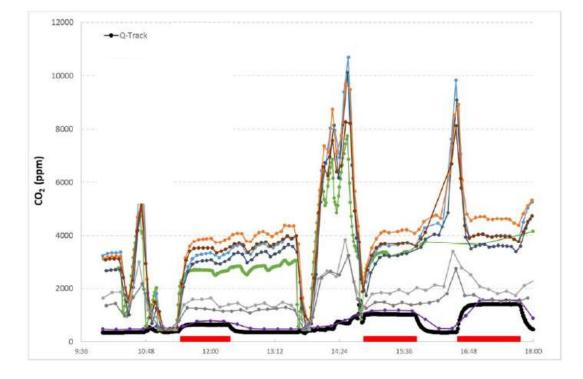
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Challenge ❷
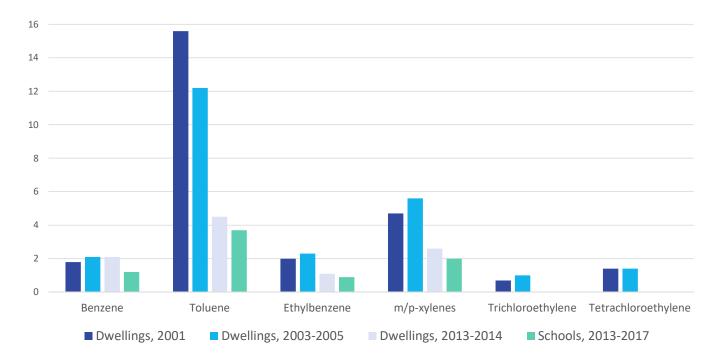
Identify the "key/emerging compounds"

What the relevant airborne pollutants to look for?

Median concentrations in µg/m^3

(Kirchner et al., 2007; Canha et al., 2016;
Derbez et al., 2018; Dassonville et al., 2019)

New uses and habits ... new indoor pollution

(Salthammer et al., 2011)

(Schripp et al., 2013)
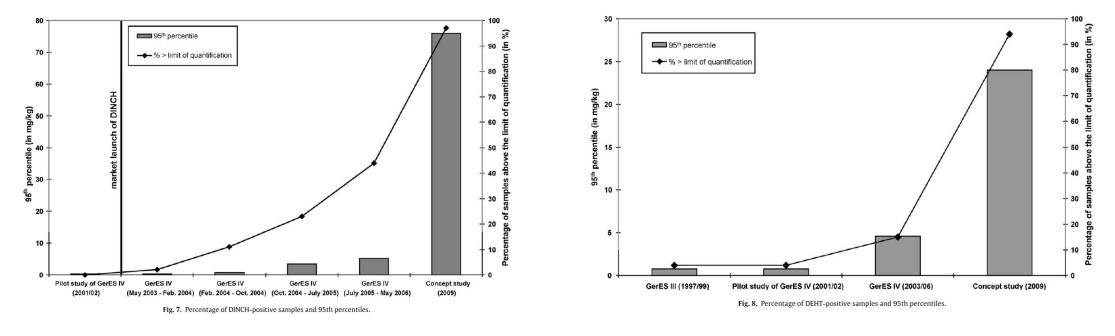
(Azimi et al., 2016)

Images: Pixabay

Emerging chemicals

Fig. 7. Percentage of DINCH-positive samples and 95th percentiles.

DINCH in German dwellings (settled dust)

Fig. 8. Percentage of DEHT-positive samples and 95th percentiles.

DEHT in German dwellings (settled dust)

(Nagorka et al., 2011)

Inventory of substances potentially present in indoor air

- In the frame of the IAQ Observatory: regular review of the literature on what is measured in indoor environment in the world

  o 2002: **70 substances** were listed

  o 2005: **99 substances** were listed

  o 2010: **1026** substances were listed

  o Last review, in 2018: **2741 substances** were listed
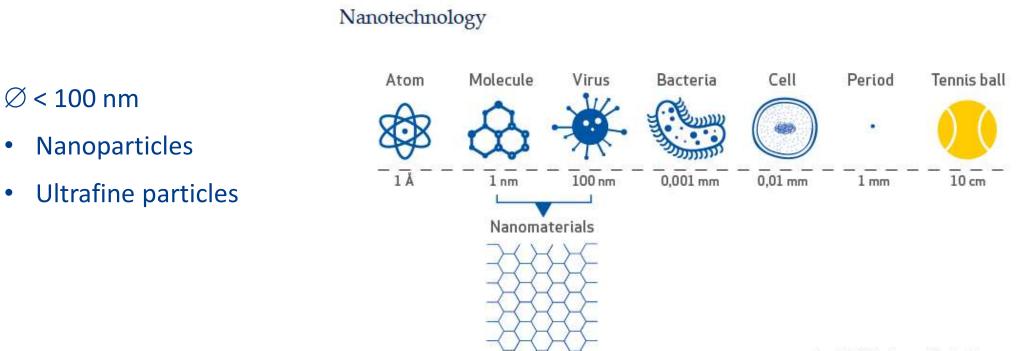
Non-targeted analysis

- **High throughput analytical techniques** that allow the rapid characterization of thousands of never-before-studied compounds (Sobus et al., US-EPA, 2017) in environmental or biological samples

- Application to settled dust samples (Rostkowski et al., 2019, EU NORMAN network):

  → **2350 substances** were identified with certainty or acceptable confidence

And what about the nano?

$\varnothing$ < 100 nm

- Nanoparticles

- Ultrafine particles

Nanotechnology

Atom — 1 Å
Molecule — 1 nm
Virus — 100 nm
Bacteria — 0,001 mm
Cell — 0,01 mm
Period — 1 mm
Tennis ball — 10 cm

Nanomaterials
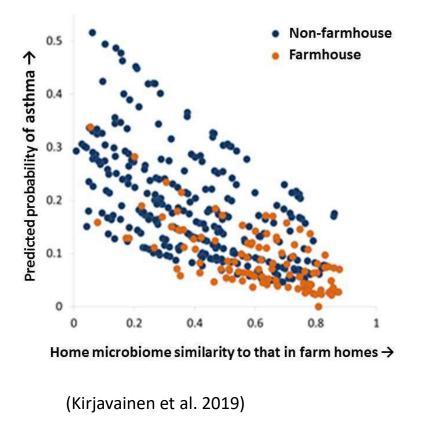
Copyright: 2016 © European Chemicals Agency

The indoor microbiome

(Kirjavainen et al. 2019)

From the **hygiene hypothesis** (Gerrard et al. 1976) to the **microbiome rewilding hypothesis** (Mills et al.2017) for health promotion via environmental microbial exposure

For ex.: urban planning & green spaces, pro-microbial cleaning
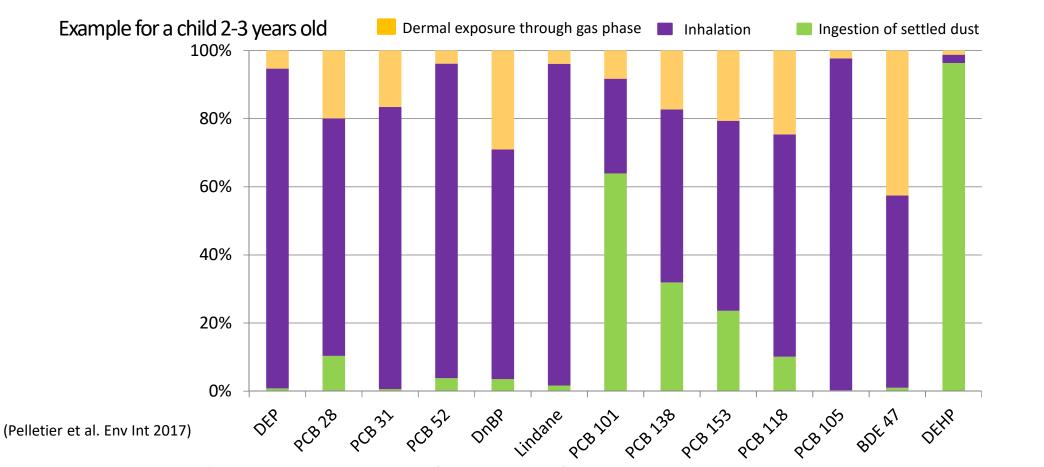
Remaining questions:

- What constitutes a health promoting indoor microbiota?
- When is exposure most beneficial, where should it happen, and in what way (route of exposure)?

Courtesy: Martin Täubel, THL

Challenge ❸

Need for an integrated approach

Considering exposure through different routes

Example for a child 2-3 years old

Legend: Dermal exposure through gas phase (orange) · Inhalation (purple) · Ingestion of settled dust (green)

Categories: DEP, PCB 28, PCB 31, PCB 52, DnBP, Lindane, PCB 101, PCB 138, PCB 153, PCB 118, PCB 105, BDE 47, DEHP

(Pelletier et al. Env Int 2017)
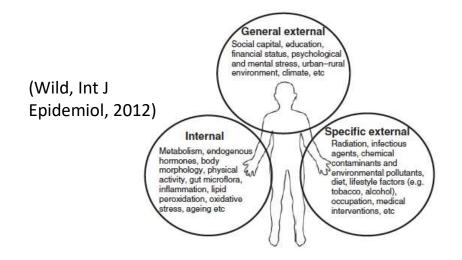
The concept of exposome

Editorial (2005)

**Complementing the Genome with an "Exposome":
The Outstanding Challenge of Environmental
Exposure Measurement in Molecular Epidemiology**

Christopher Paul Wild
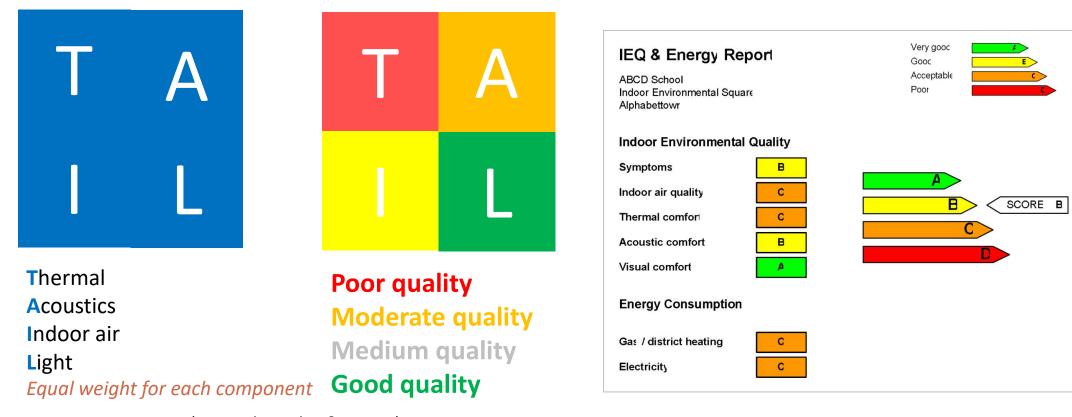
Molecular Epidemiology Unit, Centre for Epidemiology and Biostatistics, Leeds Institute of Genetics, Health and Therapeutics, Faculty of Medicine and Health, University of Leeds, Leeds, United Kingdom

(Wild, Int J Epidemiol, 2012)

General external
Social capital, education, financial status, psychological and mental stress, urban–rural environment, climate, etc

Internal
Metabolism, endogenous hormones, body morphology, physical activity, gut microflora, inflammation, lipid peroxidation, oxidative stress, ageing etc

Specific external
Radiation, infectious agents, chemical contaminants and environmental pollutants, diet, lifestyle factors (e.g. tobacco, alcohol), occupation, medical interventions, etc

From IAQ to IEQ

T A
I L

T A
I L

IEQ & Energy Report

ABCD School
Indoor Environmental Square
Alphabettowr

Very good
Good
Acceptable
Poor

Indoor Environmental Quality

Symptoms — B
Indoor air quality — C
Thermal comfort — C
Acoustic comfort — B
Visual comfort — A

SCORE B

Energy Consumption

Gas / district heating — C
Electricity — C

Thermal
Acoustics
Indoor air
Light
Equal weight for each component

Poor quality
Moderate quality
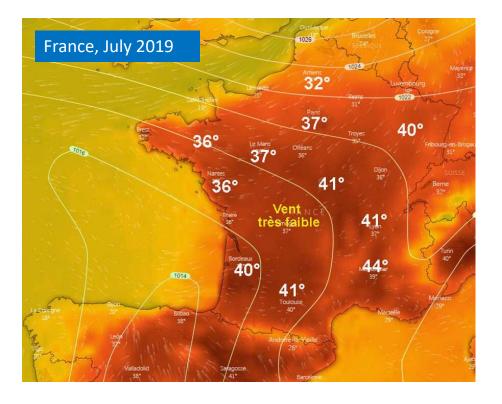**Medium quality**
Good quality

(Wargocki et al., E&B, 2021)

(Boerstra et al., BBA)

Building energy retrofit: don't forget IEQ

France, July 2019

Building energy retrofit: don't forget IEQ

Median radon concentrations in dwellings (n = 3233)

en Bq.m⁻³

Category	Value
After energy retrofit	180
Without energy retrofit	114

(Collignan et al., J Env Radioact 2016)

Pie chart legend:
- New windows (39%)
- New windows and envelope insulation (25%)
- New windows and ventilation (4%)
- Envelope insulation (8%)
- Envelope insulation and ventilation (3%)
- New windows, envelope insulation and ventilation (18%)
- Unknown (3%)

Ventilation is considered in only 25% of the building retrofits

Circular economy: don't forget IAQ

(2018)

As a conclusion

- **Indoor air quality: at the crossroads of global environmental and societal issues**

- **Research challenges**: to identify pollutants related to health effects

- **Technical challenges**: IAQ is an opportunity for innovation

- **Communication challenges**: to provide relevant information to policymakers, building owners and general public

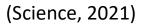# The current pandemic may have helped raising awareness

POLICY FORUM

INFECTIOUS DISEASE

A paradigm shift to combat indoor respiratory infection

Building ventilation systems must get much better

By Lidia Morawska, Joseph Allen, William Bahnfleth, Philomena M. Bluyssen, Atze Boerstra, Giorgio Buonanno, Junji Cao, Stephanie J. Dancer, Andres Floto, Francesco Franchimon, Trisha Greenhalgh, Charles Haworth, Jaap Hogeling, Christina Isaxon, Jose L. Jimenez, Jarek Kurnitski, Yuguo Li, Marcel Loomans, Guy Marks, Linsey C. Marr, Livio Mazzarella, Arsen Krikor Melikov, Shelly Miller, Donald K. Milton, William Nazaroff, Peter V. Nielsen, Catherine Noakes, Jordan Peccia, Kim Prather, Xavier Querol, Chandra Sekhar, Olli Seppänen, Shin-ichi Tanabe, Julian W. Tang, Raymond Tellier, Kwok Wai Tham, Pawel Wargocki, Aneta Wierzbicka, Maosheng Yao

(Science, 2021)

Thank you for your attention!

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