Insights into indoor air quality: Beyond CO_2 to chemical and microbial pollutants

Belgian One Health seminar 'Innovation'

29/01/2024

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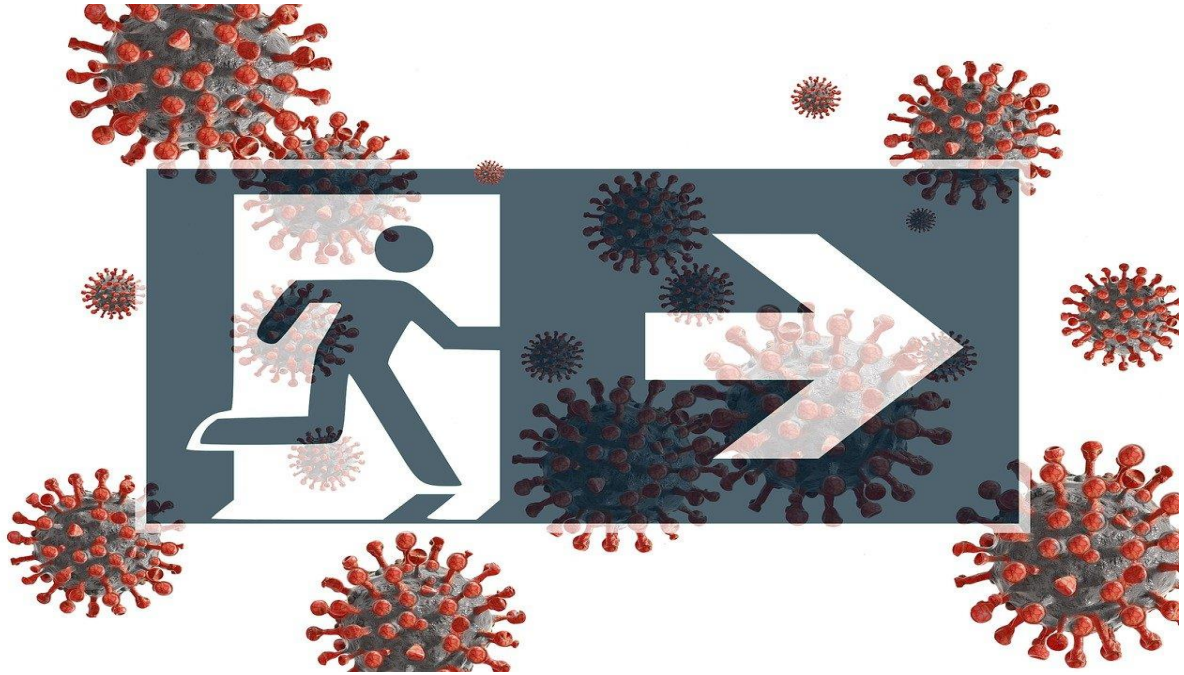
Context

COVID-19 pandemic highlighted **need to prioritize strategies** for **improving indoor air quality** in the post-pandemic period.



➔**Indoor air quality in public spaces?**




Indoor air pollutants

Indoor air quality = CO_2?

CO_2 [ppm]	Air Quality
2100	BAD Heavily contaminated indoor air Ventilation required
2000	
1900	
1800	
1700	
1600	
1500	MEDIOCRE Contaminated indoor air Ventilation recommended
1400	
1300	
1200	
1100	
1000	FAIR
900	
800	GOOD
700	
600	EXCELLENT
500	
400	

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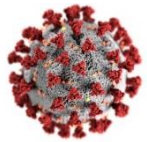
Indoor air pollutants

Indoor air quality ➔ Indoor environment ➔ Chemical + microbial sources & exposures



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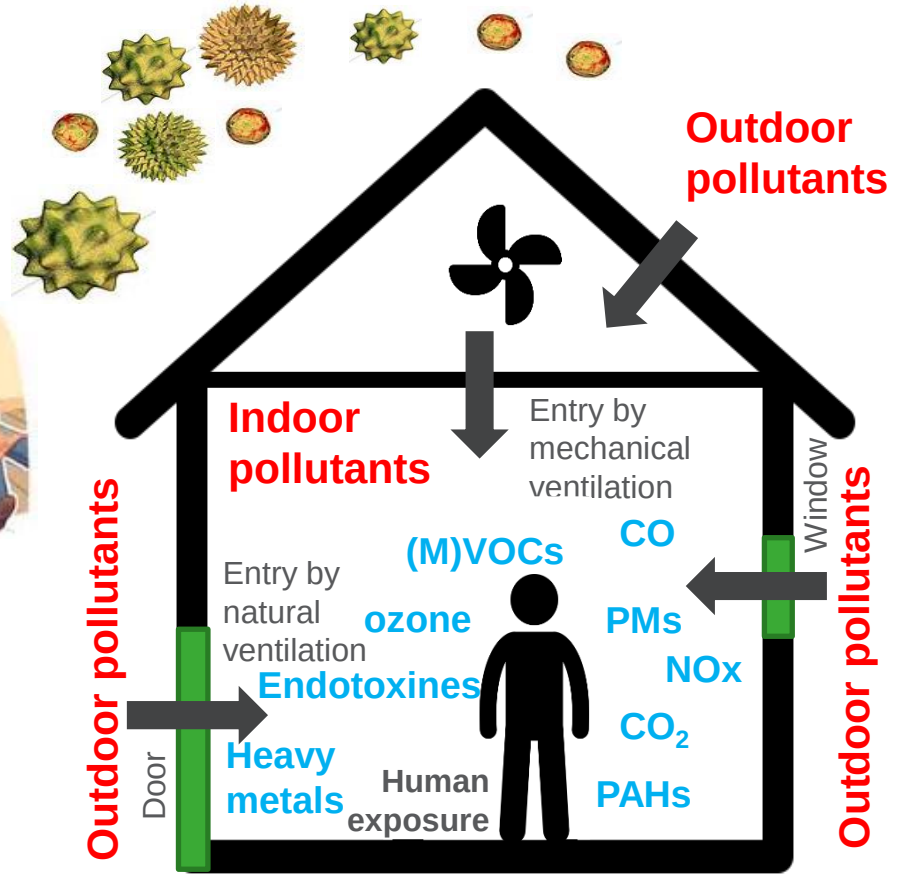
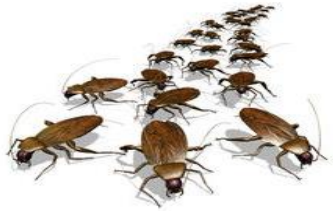
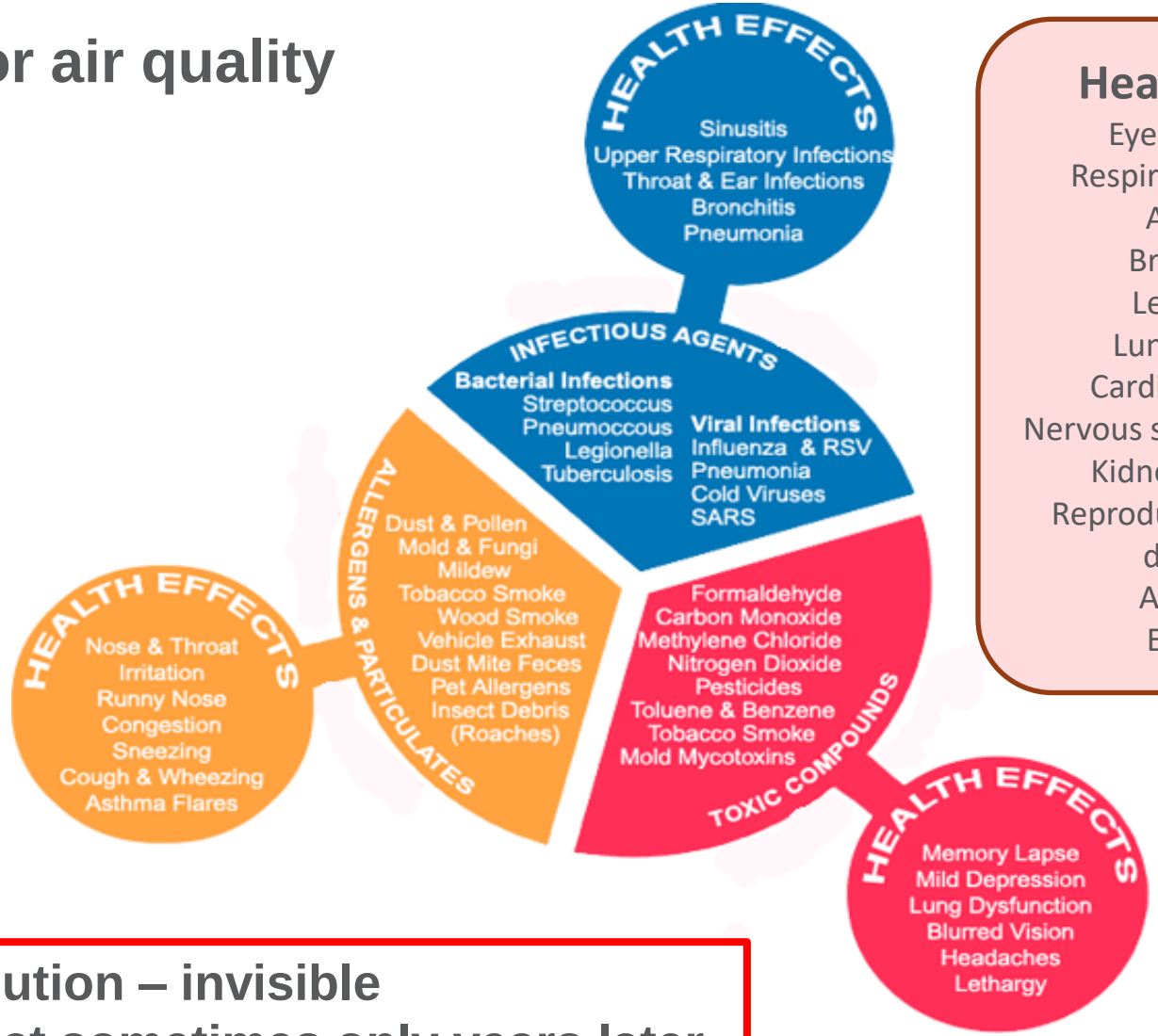




Complex mixture

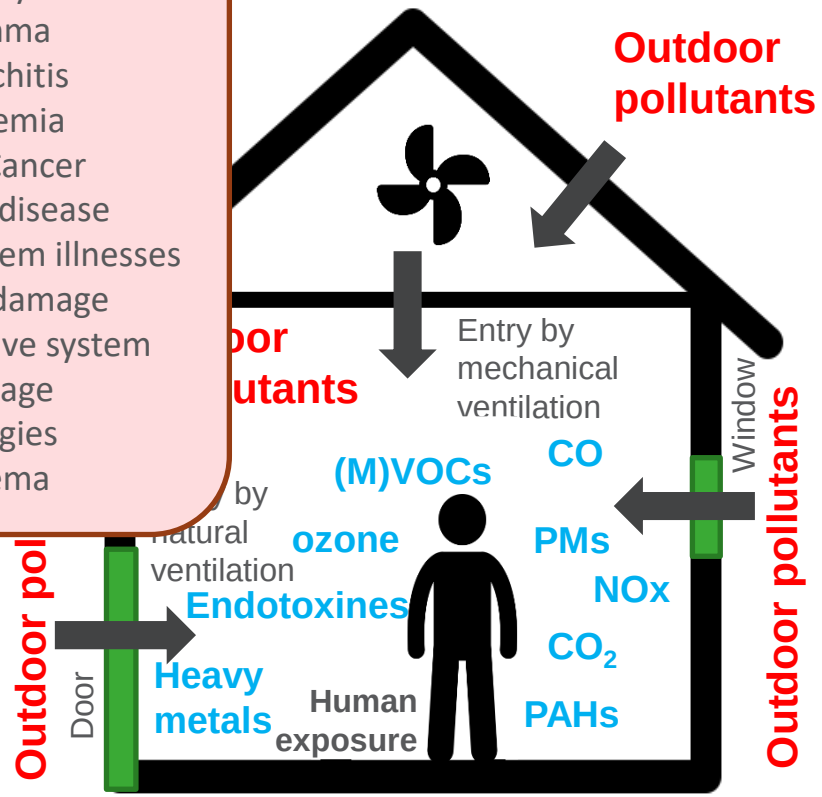
Indoor air pollutants

Indoor air quality



Health risks

Eye irritation
Respiratory illness
Asthma
Bronchitis
Leukemia
Lung Cancer
Cardiac disease
Nervous system illnesses
Kidney damage
Reproductive system damage
Allergies
Eczema

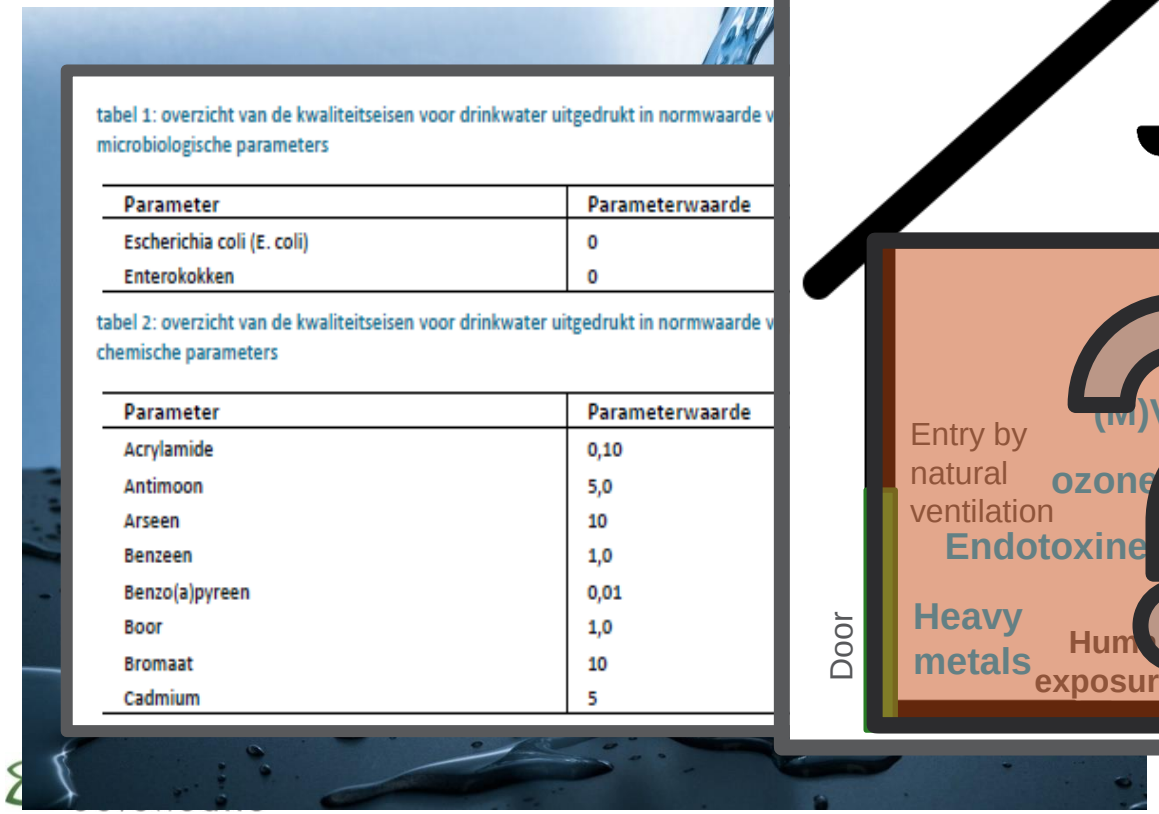


Complex mixture

Air pollution – invisible
→ Effect sometimes only years later

Need for improvement of Indoor Air Quality (IAQ)

- We spend most of our time (90%) indoor
- Most studies on ambient outdoor air, less on indoor air
- Outdoor air and drinking wa… air



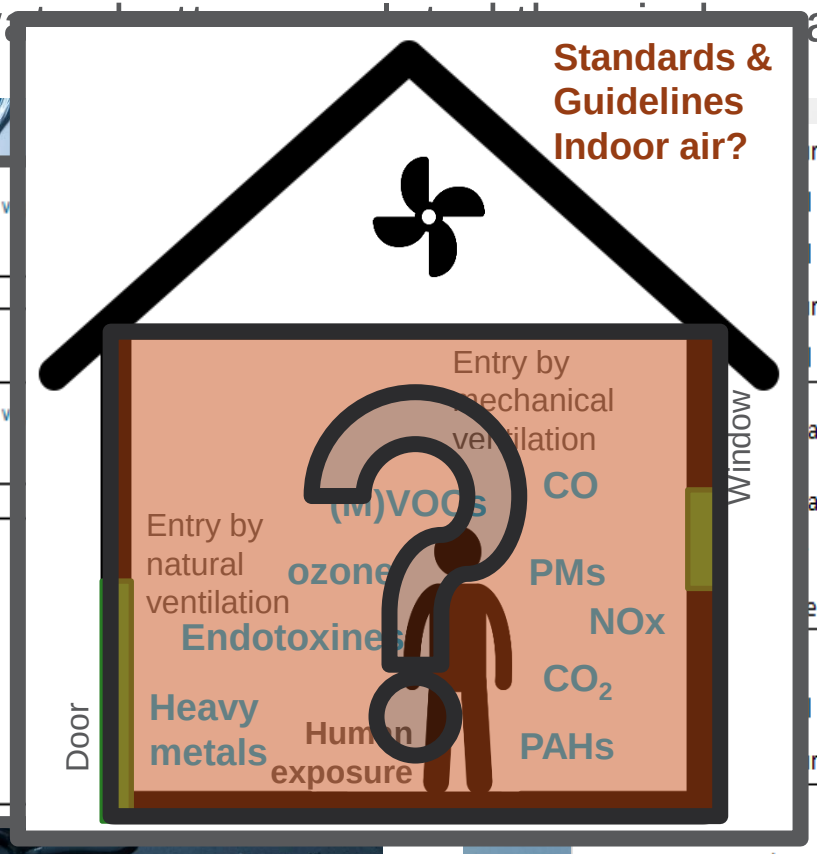
tabel 1: overzicht van de kwaliteitseisen voor drinkwater uitgedrukt in normwaarde v… microbiologische parameters

Parameter	Parameterwaarde
Escherichia coli (E. coli)	0
Enterokokken	0

tabel 2: overzicht van de kwaliteitseisen voor drinkwater uitgedrukt in normwaarde v… chemische parameters

Parameter	Parameterwaarde
Acrylamide	0,10
Antimoon	5,0
Arseen	10
Benzeen	1,0
Benzo(a)pyreen	0,01
Boor	1,0
Bromaat	10
Cadmium	5

Quality norms Belgium (VMM report 2021)



		EU Air Quality directives 2008/50/EC	WHO 2021
	Target value		15 µg/m³
	Limit value	25 µg/m³	5 µg/m³
	Indicative limit value	20 µg/m³	
	Limit value	50 µg/m³	45 µg/m³
	Limit value	40 µg/m³	15 µg/m³
…aily 8-hour mean	Target value	120 µg/m³	
…aily 8-hour mean	Long-term objective	120 µg/m3	
	Target value		100 µg/m³
…eason [a]	Target value		60 µg/m³
	Limit value	200 µg/m³	200 µg/m³
	Limit value	40 µg/m³	10 µg/m³
	Target value		25 µg/m³
	Limit value	350 µg/m³	
SO_2 24-hour	Limit value	125 µg/m³	40 µg/m³

2008/50/EC & WHO guidelines 2021

Chemical indoor pollutants - guidelines

Table 1. The potential health effects and recommended levels of indoor air pollutants.

Air Pollutant	Potential Health Effects	IAQ Code of Practice		
		ASHRAE	Singapore Standard SS 554	WHO 2006 Guidelines
Carbon Dioxide	Headache/Fatigue/Nausea/Dizziness	1000 ppm	700 ppm above outdoor	N/A
Carbon Monoxide	Fatigue/Impaired vision/Reduced brain function/Nausea/Headaches/Dizziness/Flu-like symptoms/Fatal	9 ppm	9 ppm	6 ppm
Formaldehyde	Asthma/microvascular leakage/cancer	0.1 ppm (office) 0.04 ppm (home)	0.1 ppm	0.1 ppm
Nitrogen Dioxide	Eye, nose, throat irritation/Acute or chronic bronchitis/Respiratory infections	N/A	N/A	200 $\mu g/m^3$
Ozone	Respiratory illness, such as cardiovascular mortality	N/A	50 ppb	60 ppb
TVOCs	Eye, nose and throat irritation/Nausea/Headaches, loss of coordination/Damage to liver, kidney, and central nervous system/Skin irritation	N/A	3000 ppb	N/A
Particulate Matter	Eye, nose, and throat irritation/Aggravation of respiratory tract related ailments	50 $\mu g/m^3$ ($PM_{10}PM_{10}$)	50 $\mu g/m^3$ ($PM_{10}PM_{10}$)	50 $\mu g/m^3$ ($PM_{10}PM_{10}$) 25 $\mu g/m^3$ ($PM_{2.5}PM_{2.5}$)

ASHRAE: standard for ventilation design
Singapore: standard tropical climate zones
WHO: health guidelines

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Microbial indoor pollutants - guidelines

- No health based standards
  - Personal
- Microorganisms are part of the natural living environment
- Different guidelines for different regions (Flanders, Wallonia and Brussels)
- No standardisation in interpretation / sampling

	Overview of the Regional Guidelines on micro-organisms		
Community		Guideline	Contents
Flanders	Moulds	*"Brochure Wonen gezondheid, 3e editie, Ministerie van de Vlaamse Gemeenschap 2005/2009"*	Interpretation for the occurrence of moulds in indoor air: • very low < 50 CFU/m³ • low < 200 CFU/m³ • moderate < 1000 CFU/m³ • high < 10.000 CFU/m³ • very high > 10.000 CFU/m³ (= maximum value) Table biotic factors : • orientation value total moulds: < 200 CFU/m³ • recommended value for individual moulds < 50 CFU/m³ (exception *Cladosporium*), *Alternaria sp* < 500 CFU/m³, *Cladosporium sp* < 500 CFU/m³, • Toxic moulds: recommended absence (*Aspergillus sp, Fusarium sp, Penicillium sp, Stachybotrys sp*)
	Bacteria	*"Brochure Wonen gezondheid, 3e editie, Ministerie van de Vlaamse Gemeenschap 2005/2009"*	Interpretation for the occurrence of bacteria in indoor air: • very low < 100 CFU/m³ • low < 500 CFU/m³ • moderate < 2500 CFU/m³ • high < 10.000 CFU/m³ • very high > 10.000 CFU/m³ (= maximum value) Table biotic factors: • recommended value for bacteria: 10.000 CFU/m³ (overload of gram+)

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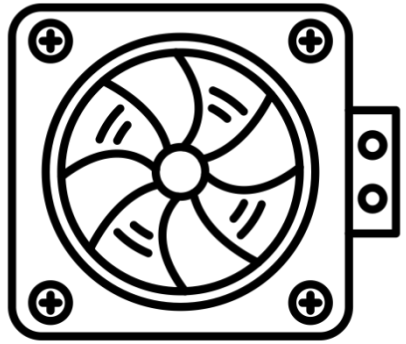
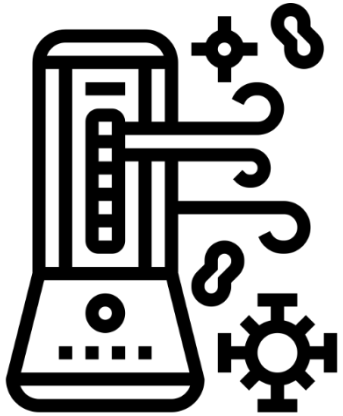
Need for improvement of Indoor Air Quality (IAQ)

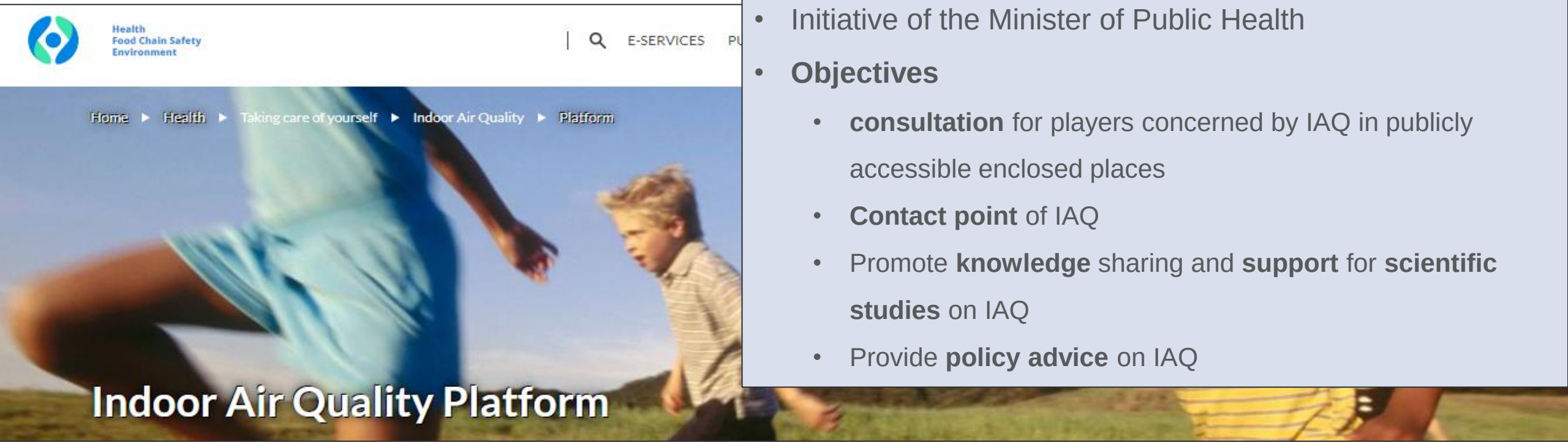
- Ventilation
  - Starting 70’s : better insulation of houses
    - Less natural ventilation
  - More recently - new materials – new toxic emissions?
  - Need for guidelines/standards of use & maintenance of ventilation systems
- Air purification
  - Supplementary solution when ventilation not sufficient
  - Safety?
  - Regulation needed





Belgium Clean Air Law – Indoor Air Quality Platform

- 6 November 2022 **– new law** aiming at **improving indoor air quality (IAQ)** of enclosed **areas** accessible to the **public** (pub, restaurant, cinema, clubs, fitness centers, …)
- Focus on
  - limiting the **spread of airborne viruses**
  - use of **ventilation and air purification** can prevent the accumulation of pollutants

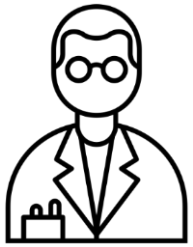


- Initiative of the Minister of Public Health
- **Objectives**
  - **consultation** for players concerned by IAQ in publicly accessible enclosed places
  - **Contact point** of IAQ
  - Promote **knowledge** sharing and **support** for **scientific studies** on IAQ
  - Provide **policy advice** on IAQ

Indoor Air Quality Platform

- **Collaboration of different people on the field**

Policy makers
Experts of relevant administrations



Scientists

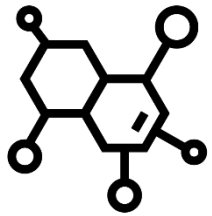
Collaboration with FPS Health
“Indoor Air”

Tasks of Sciensano – Scientific input

- Selection of **most important indoor pollutants**
- **Chemical and microbial characterization** of indoor air in public spaces
- Define **healthy indoor air** (at chemical & microbial level)
  → establishment of an “**indoor barometer**”
  ➔Contribute to define norms
  (cfr drinking water legislation)
- Study the relationship between **indoor and outdoor air**
- Study influence of ventilation and air filters
- Study the influence of the different sources of air pollution (furniture, candles, etc)
- Study the health effects of indoor air pollutants

Selection of most important chemical and microbial indoor pollutants

- List based on literature search/ EU/WHO projects
- 245 pollutants listed (125 chemical and 120 microbial)
- Guidelines for EU/WHO/separate countries
- **List sent to experts** (national and international) – feedback requested on:
  - Completeness of list
  - Comments on measurement & sampling methods
  - **Shortlist?**



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Chemical indoor pollutants

- Input from national (6) & international (5) experts

Sampling + measurement

- Online/sensor measurement not always reliable – calibration!
- Don't limit to sensors but also use analytical techniques (lab)
- Some components difficult to measure (Semi-VOCs, ….)

➔ **Combination of online/real-time + offline/ lab analysis**

Ventilation very important to take into account

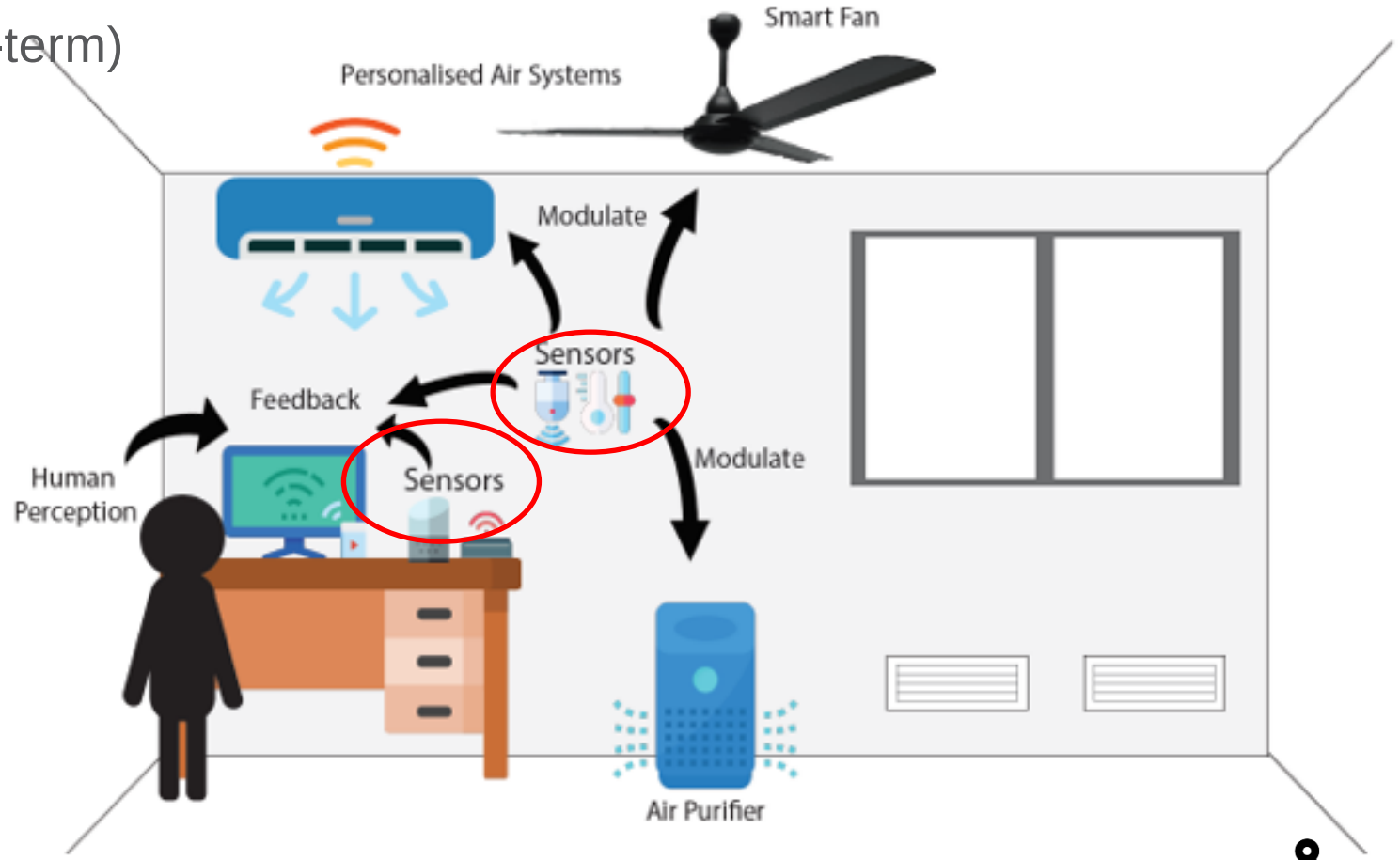
- Big differences according to ventilation possibilities

Shortlist

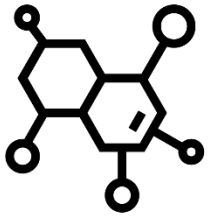
- **CO_2** + Ventilation
- Carbon monoxide (CO) – special situations
- **NO_2/NO** – external traffic
- **Ozone**
- **Particulate matter (PM)**
- Black carbon (BC)
- Glycol ethers
- Chloride compounds
- **Volatile Organic Components (VOCs)**
  - **Benzene**
  - Toluene
  - Xylenes (m, p, o)
  - **Formaldehyde**
  - **Acetaldehyde**
  - Trichloroethylene
  - Tetrachlororethylene
  - Styrene
  - Limonene
  - Pinene
  - Acrolein
- Semi-VOCs
  - Benzo(a)pyrene
  - Naphtalene
- Other : **Microclimate parameters (T, RH, p) , noise**

Focus on sensors

- Continuous measurement (long-term)
- (Trans)portable
- Active measurement
- Good performance
- Cheap



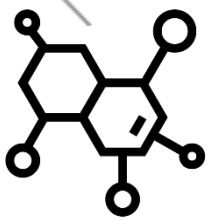
Chemical pollutants



✅

Microbial pollutants

❌



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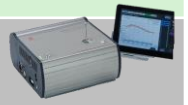
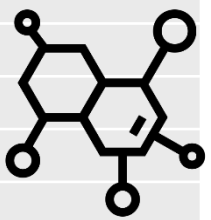
Selection of purchased sensors

	sensors					reference instruments		
	 Ellona - **POD 2**	 Ellona - **WT1**	 Ethera - **Mini XT Urban (NO_2/O_3)**	 Ethera - **Nemo Audit (for rent)**	 **AQMesh**	 2B Technologies - **POM**	 Aethlabs - **MA200**	 **MiniWRAS**
	indoor	outdoor	indoor	indoor	indoor + outdoor	indoor + outdoor*	indoor + outdoor*	indoor + outdoor*
CO_2	✓	✓		✓				
CO	✓				✓			
NO_2	✓	✓	✓		✓			
NO		✓						
O_3	✓	✓	✓		✓	✓		
$PM_{2.5}$/PM_{10}	✓	✓	✓	✓	✓			✓
TVOCs	✓	✓	✓		✓			
LVOCs			✓	✓				
formaldehyde	✓			✓				
BC							✓	
$PM_{0.1}$ (UFP)	✓ ($PM_{0.3}$)	✓ ($PM_{0.3}$)						✓
Rel. Humid.	✓	✓	✓	✓	✓			
Temperature	✓	✓	✓	✓	✓			
Pressure	✓	✓		✓	✓			
Noise	✓	✓			✓			

comparison

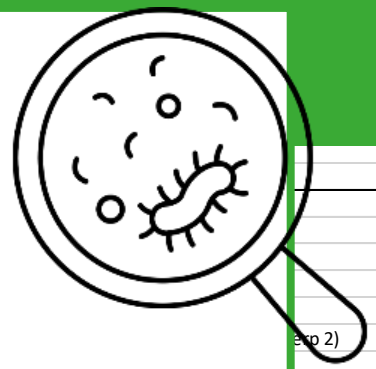
* weatherproof case



Microbial pollutants

bacteria	fungus
Chlamydia pneumoniae	Pneumocystis jiroveci
Chlamydia psittaci	Chaetomium spp.
Moraxella catarrhalis	Stachybotrys spp.
Klebsiella pneumonia	Stachybotrys chartarum
Staphylococcus spp.	Fusarium sp
Staphylococcus aureus (SA)	Botrytis cinerea
Staphylococcus xylosus	Penicillium spp.
Staphylococcus haeolyticus	Penicillum chrysogenum
Staphylococcus saprophyticus	Aspergillus
Haemophilus Influenzae (HI)	Aspergillus versicolor
Mycoplasma pneumoniae (MP)	Aspergillus fumigatus
Streptococcus spp.	Aspergillus niger
Streptococcus pneumoniae (SP)	Aspergillus Ochraceus
Coxiella burnetii	Aspergillus nidulans
Streptomyces spp	Aspergillus flavus
Mycobacterium spp	Paecilomyces variotii
Legionella spp.	Cladosporium spp.
Legionella pneumophila (LP)	Cladosporium herbarum
Bacillus pseudomycoides	Cladosporium cladosporioides
Bacillus lentus	Cladosporium sphaerospermum
Bacillus cereus	Alternaria spp.
Bacillus licheniformis	Alternaria alternata
Bacillus pumilus	Trichoderma viride
Bacillus staerothermophilus	Exophiala jeanselmei
Thermus thermophilus	Acremonium strictum
Thermoactinomyces vulgaris	Mucor sp.
Corynebacterium spp.	Epicoccum
Micrococcus spp.	Aureobasidium pullulans
Micrococcus luteus	Chrysosporium
Macrococcus equipercicus	Wallemia sebi
Macrococcus brunensis	Phoma spp.
Janibacter anophelis/hoylei	Xeromyces
E. Coli	Phialophora spp.
Enterococcus spp.	Candida
Enterobacteriaceae	Saccharomyces
Pseudomonas stutzeri	sterile mycelia

Most important



- **Bacteria:**
  - Bacillus
  - Staphylococcus
  - Micrococcus
- **Fungi:**
  - Cladosporium
  - Alternaria
  - Penicillium
  - Aspergillus
- **Virus:**
  - Influenza
  - Coronavirus
- **Allergens:**
  - Cat allergen
  - Dog allergen
  - House dust mite allergen
- **Other :** Microclimate parameters (T, RH, p) , noise

Microbial air sampling

- No real time monitoring possible
- Focus on air sampling methods and molecular technologies
- Sampling bacteria, viruses, endotoxins, pollen, allergens
- Different methods

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Air samplers

⇒ Sampling of bacteria, viruses, pollen, allergens, toxins

⇒ Liquid sampling

Coriolis µ

AIRBIO-ONE rapid virus

Biospot-GEM

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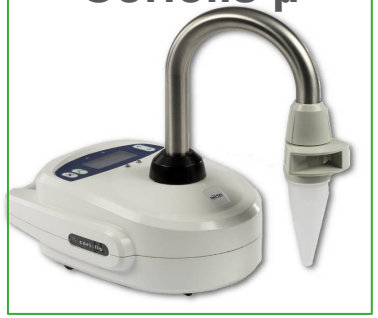
Endotoxine tester

⇒ Test concentration of endotoxins and β glucanes

Coriolis µ



Biospot-GEM

AIRBIO-ONE rapid virus

Endosafe

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Air sampler

- Detection of viruses and bacteria
- Paired with (on-site) PCR
- Cartridges

- Not real time
- Always lab time needed

AerosolSense

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Let’s get started!

First test at Sciensano offices

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Detection of activities

Ellona Nemo Audit

16/10

1092ppm

1000ppm

17/10

CO2 WHO guidelines

CO_2↑

CO_2↓

CO_2↑

476ppm (background level outdoor)

50µg/m³

PM10 (24h) WHO guidelines

22µg/m³

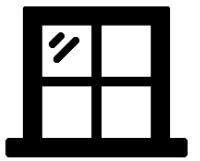
15µg/m³

PM2.5 (24h) WHO guidelines

PM↑

7µg/m³

CO_2
$PM_{10}/PM_{2.5}/PM_1$
LVOC
RH, T, p



No mechanical ventilation

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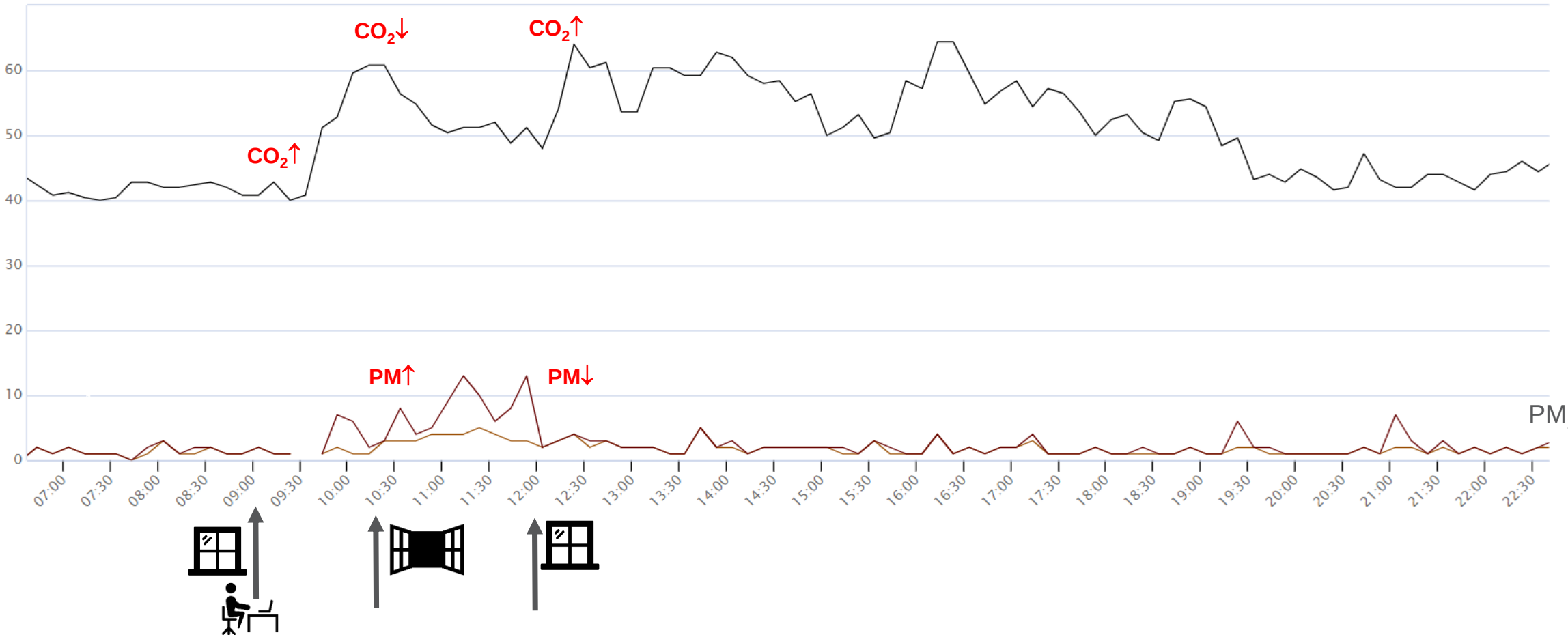
Natural ventilation

Ellona Nemo Audit



CO_2
$PM_{10}/PM_{2.5}/PM_1$
LVOC
RH, T, p

Effect of natural ventilation (windows open/closed)

Planning

- Ongoing
  - Training for use of all sensors & instruments (chemical + microbial)
  - Measurement at

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FPS Mobility (Brussels & Oostende)

- Prepare field study
  - Define set-up/design
  - Select locations

Sport centers
Cafetaria

Cultural centers

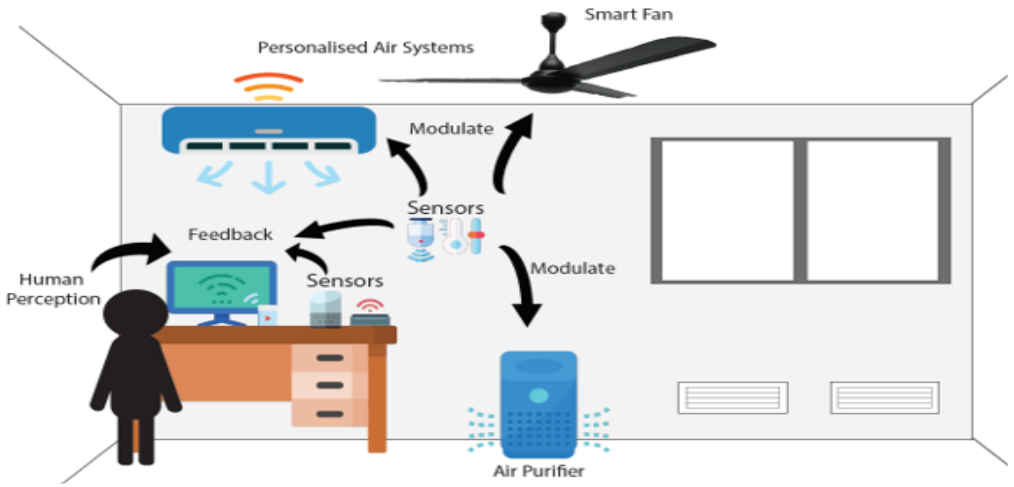
FPS Public Health

- Future (>2025)
  - Field study to assess health effects of exposure to indoor air pollution

Future – the ideal sensor

Chemical

CO, CO_2
NO_2/NOx
O_3
$PM_{10}/PM_{2.5}/PM_1/PM_{0.1}$
BC
Reliable TVOC
Formaldehyde
Acetaldehyde
Benzene
RH, T, noise



Real-time measurements
Actions based on measured values (ventilation, air cleaning, …)
Accurate
Modular
Small
Cheap
Autonomy (electric/battery)
Data accessible remotely
General autonomy (automatic calibration,…)
Certificated for measurements

Microbial

Numbers of the most important Bacteria, virusses and fungi

Detection of viability

Detection concentrations of most important allergens

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CONCLUSION

- Initiative of Minister of Public Health
- **Objective**
  - Promote **knowledge sharing** on IAQ of closed public spaces
  - **Policy advice**
- **Role of Sciensano - collaboration with FPS Health (Unit Indoor Air Quality) → Scientific input**
  - Indoor barometer (not just CO_2 → microbial and chemical)
  - Relationship between indoor and outdoor air
  - Field study in public spaces

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THANK YOU FOR YOUR ATTENTION

Questions?