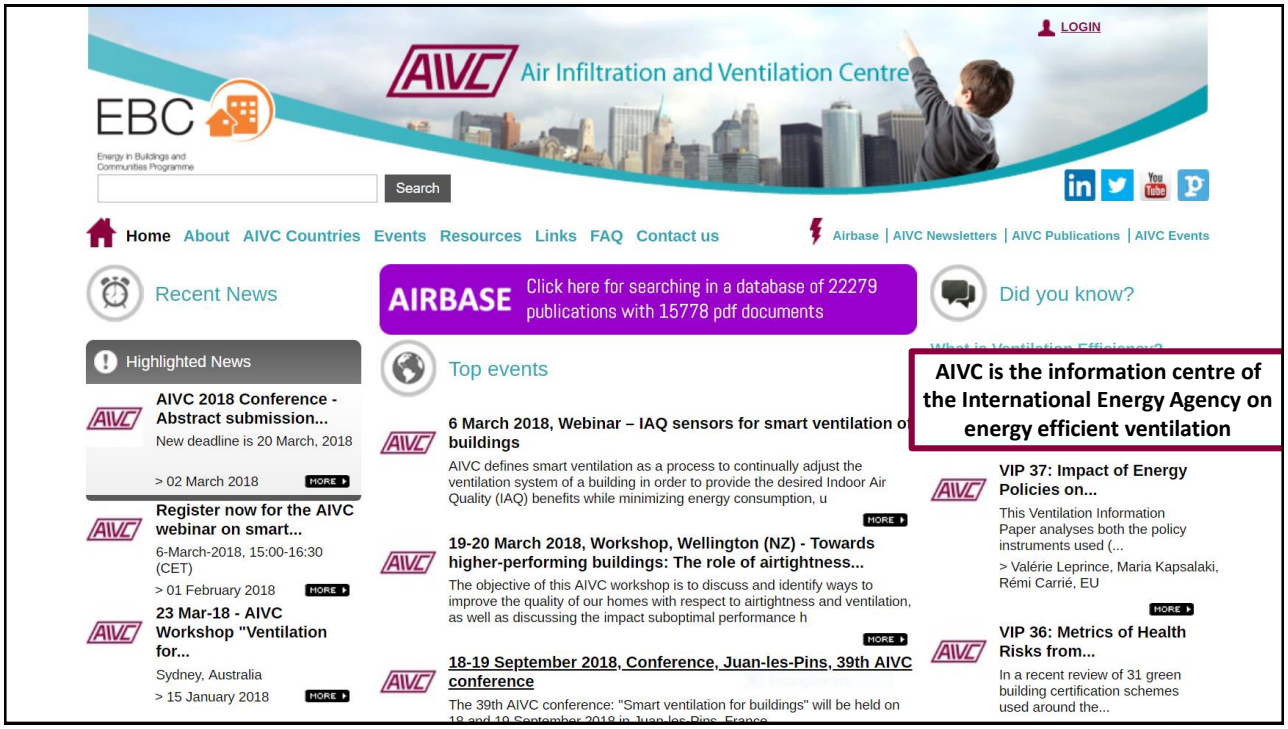
Webinar – IAQ sensors for smart ventilation of buildings

Peter Wouters – Operating Agent AIVC

Tuesday 6 March 2018



AIVC is the information centre of the International Energy Agency on energy efficient ventilation

AIVC Member countries

- Belgium
- China
- Denmark
- France
- Germany
- Italy
- Japan
- Korea
- Netherlands
- New Zealand
- Norway
- Spain
- Sweden
- United Kingdom
- United States

→ Interest from several other countries

More focusing on market implementation

AIVC

TightVent Europe

BUILDING AND DUCTWORK AIRTIGHTNESS PLATFORM

More focusing on knowledge generation aspects

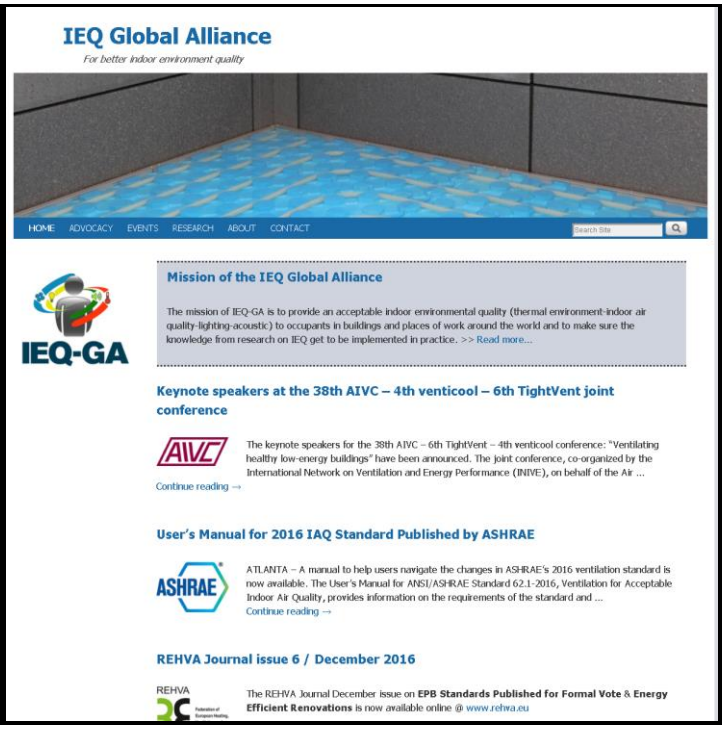
More focusing on market implementation

QUALICHeCK

Towards better quality and compliance

venticool

the international platform for ventilative cooling



AIVC Newsletter

http://subscriptions.inive.org/

Energy Efficiency and Indoor Climate in Buildings

... with specific information on AIVC, IEQ-GA and the platforms QUALICHeCK, Dynastee, venticool and TightVent

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Friday, Mar. 02, 2018 | Archives

AIVC 2018 Conference - Abstract submission deadline extended

Shared by INIVE eeig

aivc.org - The abstract submission deadline for the 39th AIVC - 7th TightVent - 5th venticool joint conference "Smart ventilation for buildings" to be held on 18 and 19 September 2018 in Antibes Juan-Les-Pins, ...

SAVE THE DATE for our upcoming webinar on ventilative cooling – 25 April 2018, 10:30-12:00 (CET)

Shared by venticool

venticool.eu - The FREEVENT project and venticool are organising the webinar: "Ventilative cooling and summer comfort: Freevent project in France" to be held on Wednesday 25 April at 10:30 AM (CET). The programme i...

AIVC Workshop on airtightness & ventilation, 19-20 March 2018, Wellington, NZ

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tightvent.eu - New Zealand homes and apartments have become more and more airtight and have reached a level of airtightness that requires dedicated ventilation. Despite the fact that there is no airtightness requir...

23 Mar-18 - AIVC Workshop "Ventilation for IAQ and cooling"

Shared by INIVE eeig

aivc.org - The AIVC (Air Infiltration and Ventilation Centre) and the Cooperative Research Centre (CRC) for Low Carbon Living warmly invite you to participate in a free, one-day workshop Ventilation for Indoor ...

AIVC Workshop on airtightness & ventilation, 19-20 March 2018, Wellington, NZ

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tightvent.eu - New Zealand homes and apartments have become more and more airtight and have reached a level of airtightness that requires dedicated ventilation. Despite the fact that there is no airtightness requir...

China joins the AIVC

Shared by INIVE eeig

aivc.org - The AIVC is very pleased to welcome China as new participating country! China will be represented in the AIVC board by Guoqiang Zhang, Dean of Institute of Sustainable

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INIVE EEIG – International Network for Information on Ventilation and Energy Performance

Editor's note

Dear Reader,

We wish you a healthy 2018!
With this monthly information paper on energy efficiency and indoor climate, we hope to keep you informed about new interesting information on the internet.

In addition, it provides information related to several specific areas of interest:
- Activities with a link to the Air Infiltration and

INIVE

Annual AIVC conferences | AIVC Workshops | AIVC Webinars | Events endorsed by AIVC

Workshop details

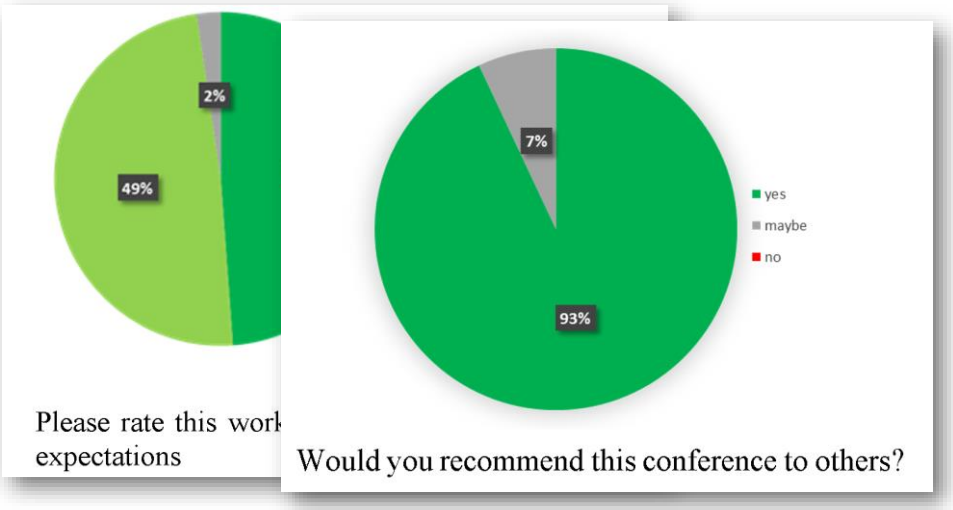
14-15 March 2017, Workshop, Brussels - Is ventilation the answer to indoor air quality control in buildings? Do we need performance-based approaches?

Brussels, Belgium 03/14/2017 - 09:15

Indoor exposure to contaminants should be minimized to avoid adverse health and comfort effects. Experience shows that this qualitative statement is difficult to translate into measurable terms, such as performance indicators or metrics, which can be used as a basis for defining and assessing requirements in regulations and standards while holistically reflecting indoor air quality. The simplest and most commonly used approaches rely on ventilation airflow rates determined by experts or codes. These approaches have fundamental shortcomings in practice for systems that do not have steady contaminant sources or do not provide a constant airflow rate, such as natural, hybrid, or demand-controlled ventilation. More sophisticated approaches can be based on health damage, pollutant exposures, or perceived air quality but they generally entail a number of assumptions about the pollutants of concern and occupant scenarios. Such methods could lead to useful metrics. However, as of today, there is no clear set of metrics that can be used to assess the overall ventilation performance of a building with regard to its indoor air quality, or used in standards or regulations.

This workshop aims to identify the pros and cons of performance-based approaches and metrics that can be considered to assess the IAQ performance of ventilation systems, as well as to draft guidelines for their use in standards and regulations.

Brussels March 2017 workshop on IAQ metrics



Ventilating healthy low-energy buildings

Smart ventilation for buildings

Topical sessions at 2018 conference …

1. IAQ metrics
2. **Smart ventilation control**
3. **Sensors for smart ventilation**
4. Rationale behind ventilation requirements and regulations
5. Utilization of heat recovery
6. Integrating uncertainties due to wind and stack effect in declared airtightness results
7. Ductwork airtightness
8. Residential cooker hoods
9. French initiatives for indoor air quality
10. **Demand controlled ventilation in French buildings – 35 years of wide scale experience**
11. Commissioning of ventilation systems – Improving quality of installed ventilation systems
12. Measurement Accuracy of air flow and pressure difference
13. Air cleaning as supplement for ventilation
14. New annex on resilient cooling
15. BIM and Construction 4.0 opportunities in relation to ventilation and airtightness

Workshops in Wellington and Sydney

19-20 March 2018, Workshop, Wellington (NZ) – Towards higher-performing buildings: The role of airtightness and ventilation

Wellington, New Zealand 03/19/2018 - 08:00

23 March 2018 Workshop Sydney (Australia) – Ventilation for IAQ and cooling

EBC

Energy in Buildings and Communities Programme

www.iea-ebc.org

Invitation to IEA EBC Annex Definition Workshop on

Resilient Cooling for Residential and Small Office Buildings

The workshop will be held on Friday, 27th April 2018, 10:00 to 17:00 at Vienna International Airport, Office Park 1.

Revision of Energy Performance of Buildings Directive

New aspect:

"Smart Readiness Indicator"

Aspects which can be included:

- Energy efficiency improvement
- Indoor climate control
- Smart grid
- …

Ventilation
Information
Paper
n° 38

March 2018

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International Energy Agency
Energy Conservation in Buildings
and Community Systems Programme

Air Infiltration and Ventilation Centre

What is smart ventilation?

François Durier, CETIAT, France
Rémi Carrié, ICEE, France
Max Sherman, LBNL, USA

Agenda of today…

- **Introduction**
  - *Peter Wouters (AIVC, Belgium)*

Now the 2 key presentations which **focus on two emerging technologies: particulate and VOC sensors**:

Evaluating particulate sensors for IAQ controls
- *Iain Walker (LBNL, USA)*

Assessment of low-cost particulate and VOC sensors
- *Laure Mouradian (CETIAT, France)*

Evaluating Particle Sensors for IAQ Controls

Iain Walker

Lawrence Berkeley National Laboratory

AIVC Webinar, March 6th 2018

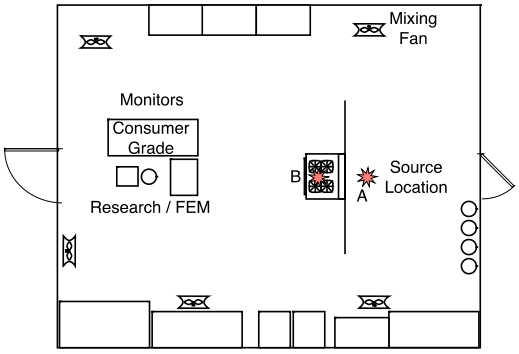
Sensing for control

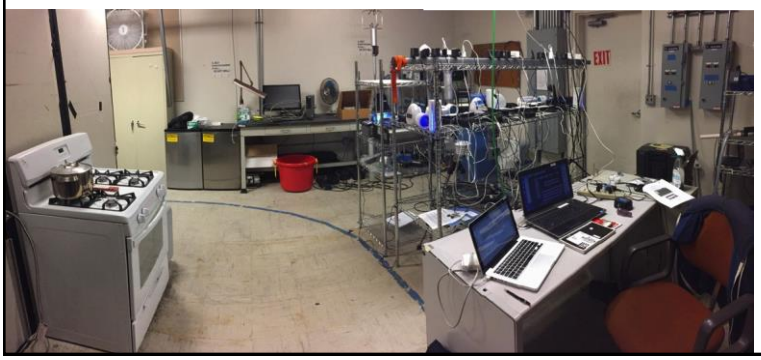
- ***Sensors*** packaged into IAQ ***monitors*** with power supply, display, internet connectivity (cloud storage)
  - Typically sensing: T, RH, PM, CO_2, VOCs
  - ***Monitor*** 250 USD/200 EUR
- ***Sensor*** 30 USD/25 EUR – light scattering (0.3 micron low limit)
- Current focus on particles – compare to reference & research grade monitors
  - Event detection
  - Is magnitude correct?
  - Impact of size distribution? What sizes are monitors sensitive to vs. what are sizes created by indoor events
  - Good enough for on/off decision for ventilation/filtration control?

Testing

Compare low-cost monitors to research and reference systems

Controlled testing in Lab
Extra tests in home





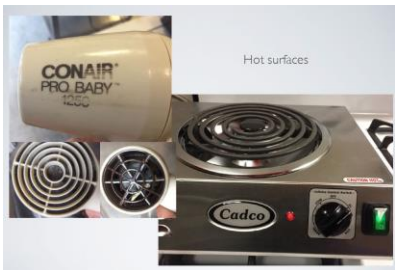
Particle Sources

General particles

Road dust, carpet, dust mop, and humidifier

Hot surfaces

Hair dryer, and electric burners



Cleaning products + ozone

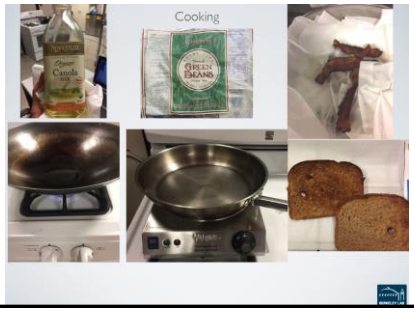
Particle Sources

Combustion

Gas burners, incense, candles, and cigarettes

Cooking

Stir fry, pancakes, bacon, heated oil, boiled water, toast, and frozen pizza



Reference Instruments ~ $35,000

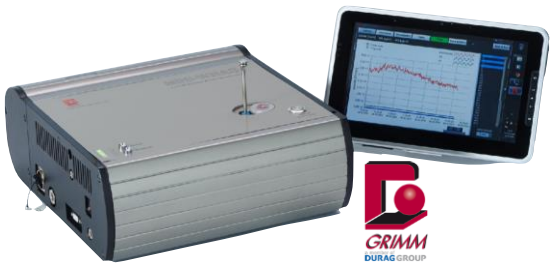
Thermo-Scientific TEOM-1405DF

ThermoFisher SCIENTIFIC

Direct Mass readings
$PM_{2.5}$, PM_{Coarse}

TEOM = Tapered Element Oscillating Mass-Balance

Grimm miniWRAS



Aerosol Spectrometer
Particle size distribution in 41 channels from 10nm up to 35μm

Research Instruments ~ $5,000-7, 000

BT-645

Met One Instruments, Inc.

ThermoFisher SCIENTIFIC pDR-1500

Used as reference for in-home measurements

Low Cost IAQ Monitors ~ 250 USD/200 EUR

AirBeam

PM, T, RH
1 sec

AirVisual Node

PM2.5, PM10,
T, RH, CO2
10 sec- 15 min

AirQualityEgg V2

PM, T, RH
1 min

AWAIR

PM, T, RH,
CO2, VOC
10 sec-5 min

Foobot

PM, T, RH,
CO2, VOC
5 min

PurpleAir V2

PM1, PM2.5,
PM10, T, RH
80 sec

Speck V2

Count, PM, T,
RH
1 min

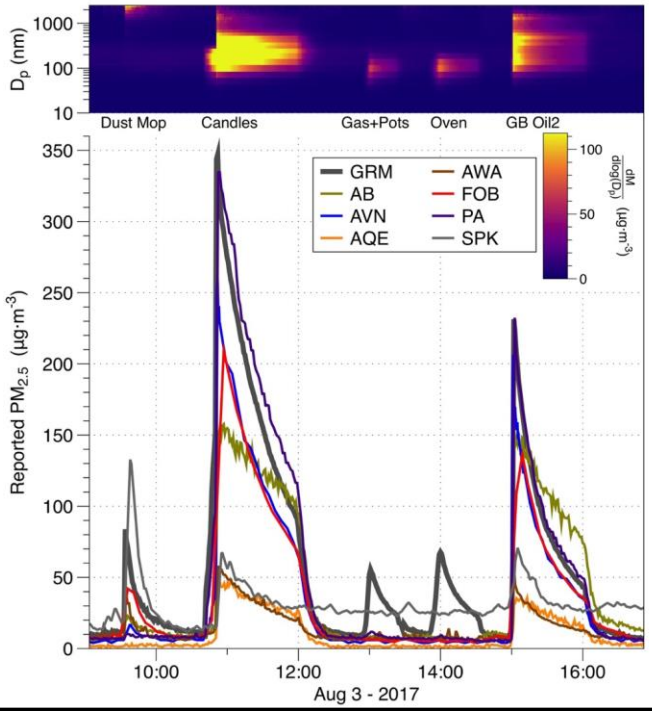
Event detection

- Some better than others

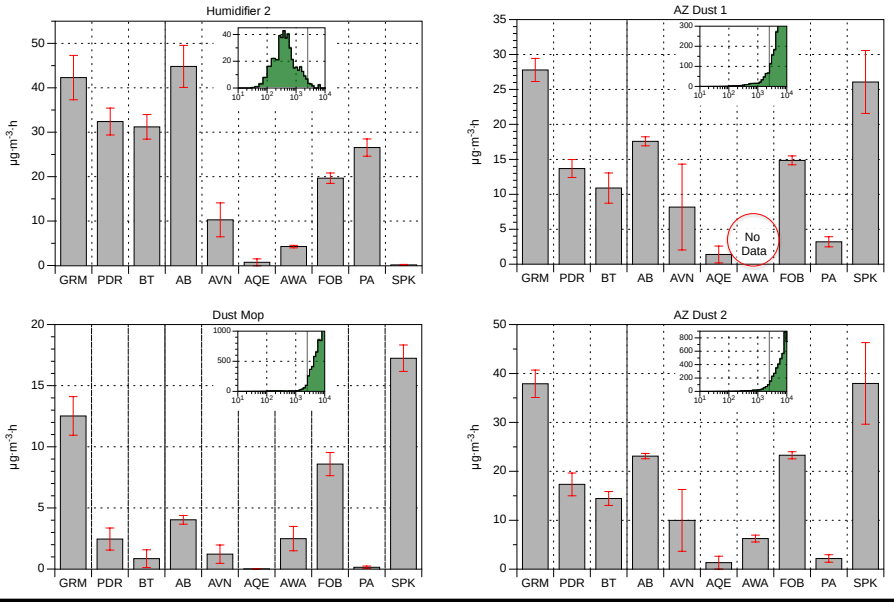
Magnitude

- Some better than others

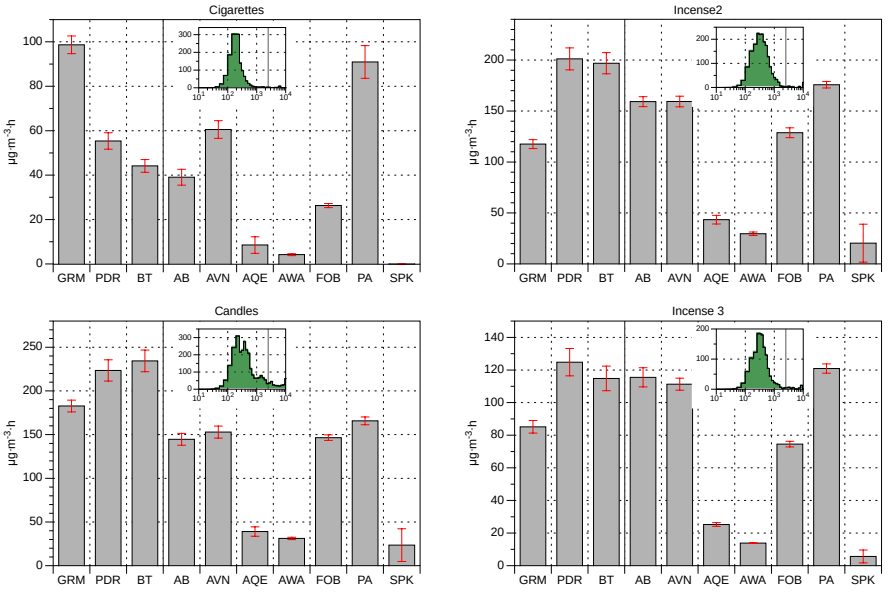
Depends on “event”
= depends on particle size distribution



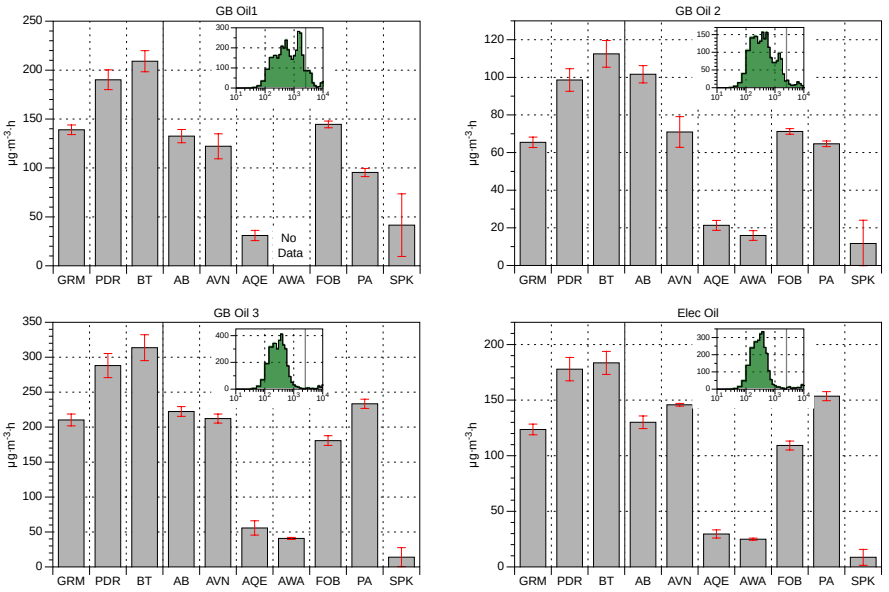
Humidifier and Dust



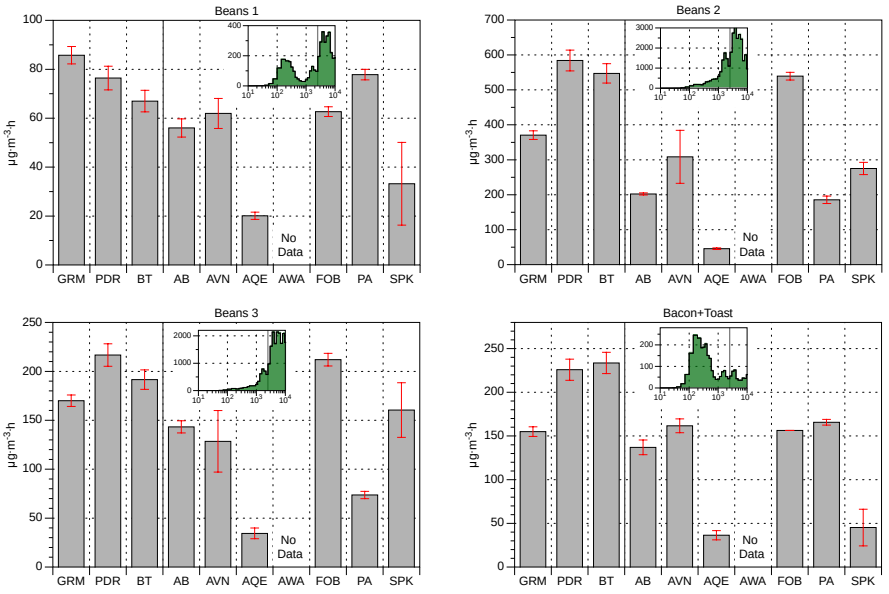
Recreational Combustion



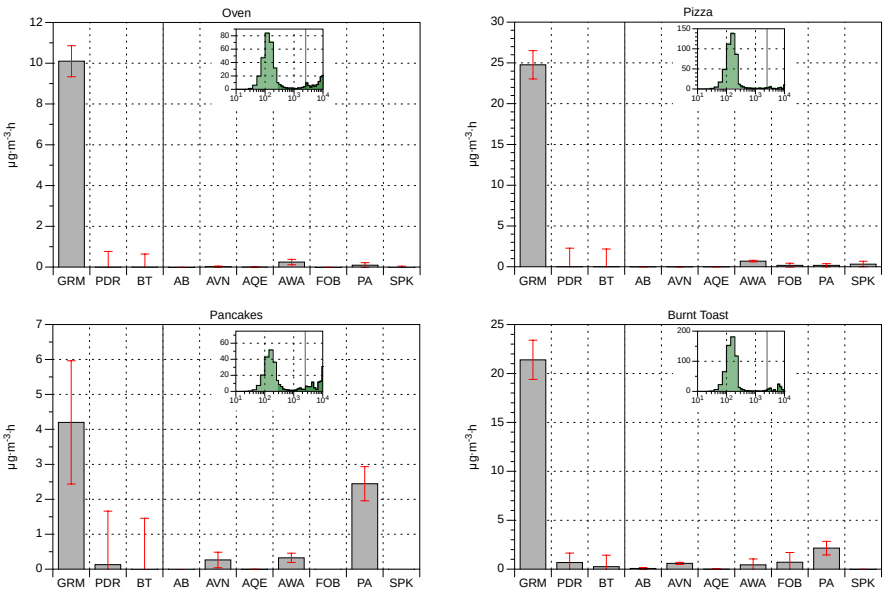
Heating Oil on Gas or Electric Burners



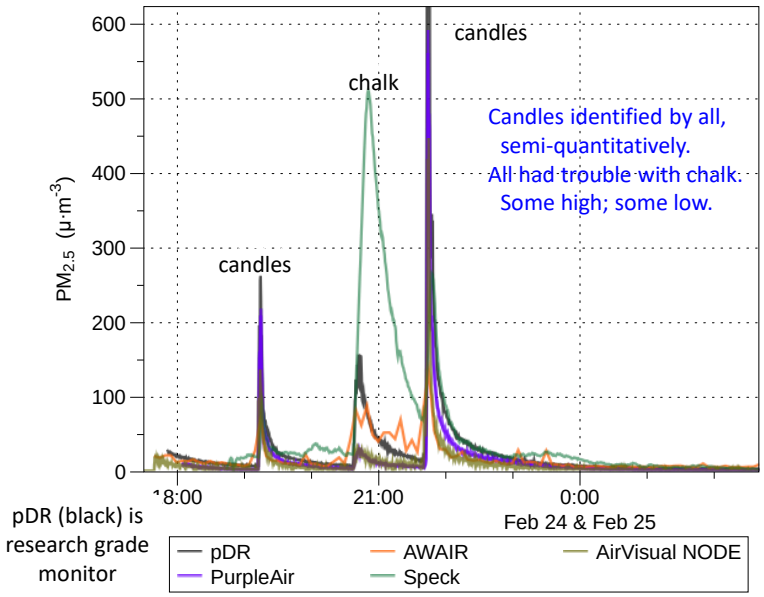
Stir-Frying and Frying + Toasting



Cooking that Emits Mostly <0.3 um Particles

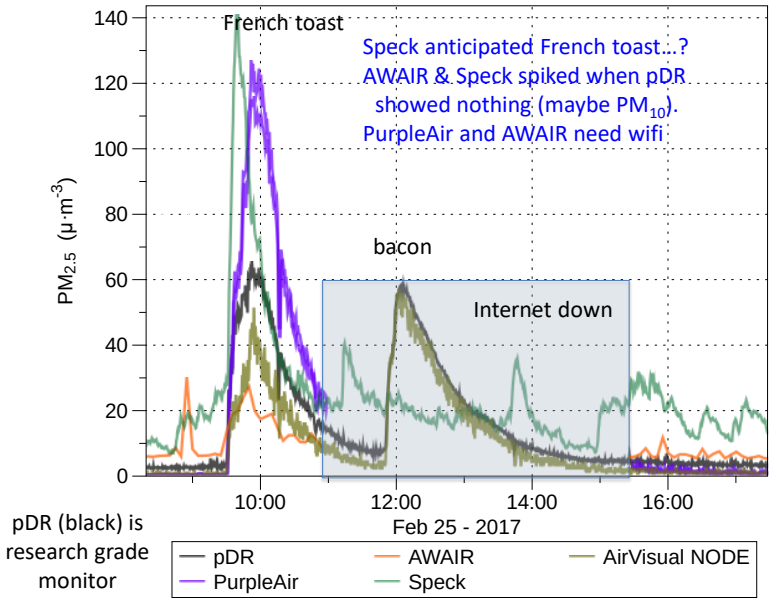


In-Home Test



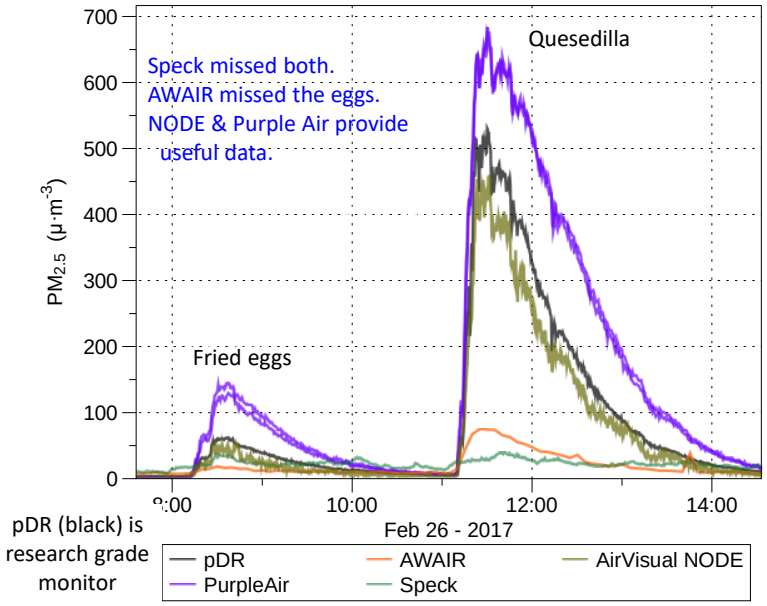
pDR (black) is research grade monitor

In-Home Test



pDR (black) is research grade monitor

In-Home Test



Other Studies – Similar Results

- EPA has done some work focusing on outdoors

  https://www.epa.gov/air-sensor-toolbox
- South Coast AQMD is working on outdoor and chamber tests

  http://www.aqmd.gov/aq-spec/home
- Carnegie Mellon has done some work and developed the SPECK

https://explorables.cmucreatelab.org/explorables/air-quality-monitor-tests/

- Air quality in China

  http://aqicn.org/sensor/

Are these monitors/sensors "good enough"?

Yes?

- Purple Air & Foobot: detected almost all sources and had enough magnitude for control

Maybe

- AirVisual & Air Beam & AWAIR: detected most sources

No

- Air Quality Egg & Speck not reliable enough

- Issues are particle size sensitivity and possibly composition
  - Nothing below 0.3 micrometers – problem for cooking!
- Need a standardized way to compare devices
- Need to check performance again after a couple of years

Connectivity

Almost all require an internet connection for cloud storage or data retrieval

- ALWAYS confirm upload otherwise data can be overwritten and lost

Almost all have an app for data viewing – particularly if they have no built-in display

Foobot & AWAIR already set up for IFTTT protocols for communicating with other devices: ifttt.com

Other devices would require custom applications to read cloud data

Build your own monitor (BYOM)

UPOD: Open source platform for mobile air quality monitoring

University of Colorado, Boulder

http://mobilesensingtechnology.com/

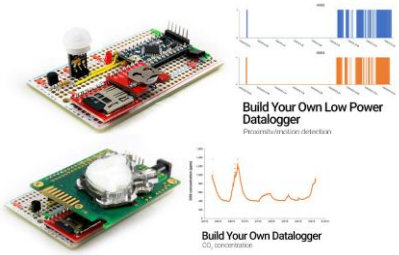
T, RH, PM, CO_2, O_3, NO_2; slots for 4 e2v MOx sensors

Open Source Building Science Sensors

Illinois Institute of Technology

http://www.osbss.com/

T, RH, CO_2, Particles, δελτα–P, equilibrium RH, light state, proximity, occupancy



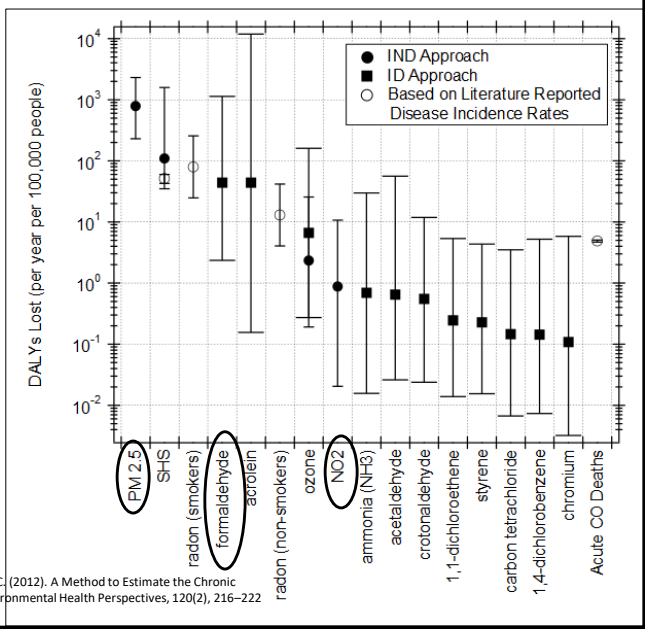
DIY / Maker offerings

- Sensor + parts kit: using same sensor as monitors
- EPA kit for schools: https://www3.epa.gov/airnow/teachers/gh_pmsensorkit_handoutandinstructions.pdf
- ~$50/50 EUR

Why Particles?

We live in a complex soup of many agents - which ones have the biggest health impact?

Disability Adjusted Life Years: DALYs



Logue, J. M., Price, P. N., Sherman, M. H., & Singer, B. C. (2012). A Method to Estimate the Chronic Health Impact of Air Pollutants in U.S. Residences. Environmental Health Perspectives, 120(2), 216–222

6 March 2018

Assessment of low-cost particulate matter and VOC sensors

Laure MOURADIAN

Purpose of the study

Assessment of « new » IAQ sensors

- Low cost stand-alone sensors for consumers
- Compact and internet-connected
- Measuring :
  - Particulate matter
  - VOCs
- Assessment of sensitivity, response time
  - On site and in laboratory
  - Regarding the nature of pollutant

Sensors tested at CETIAT

AWAIR
PM, VOCs, CO_2

LASER EGG
PM

SPECK
PM

AERECO
PM

UNI-T
PM, VOCs

FOOBOT
PM, VOCs

Few / heterogeneous information on sensors characteristics

Information available on manufacturers' technical specifications for particles measurements

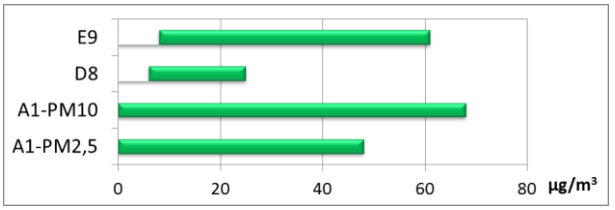
A	B	C	D	E	F
• Sensitivity: 0,3 – 10 µm • PM2.5, PM10 • PM 2.5 ±10% • Response time 10-100 ms	• Sensitivity: 0,3 - 2,5 µm • ± 4 µg/m³ or ± 20 % • Range: 0-1300 µg/m³	• Resolution 1µg/m³ • Range: 0-500 µg/m³	• Range: 0-500 µg/m³	• Sensitivity: 0,5 - 3 µm • Count of particles : ppL • Transpositio n µg/m³	• Count of particles /size • PM2,5 • PM10

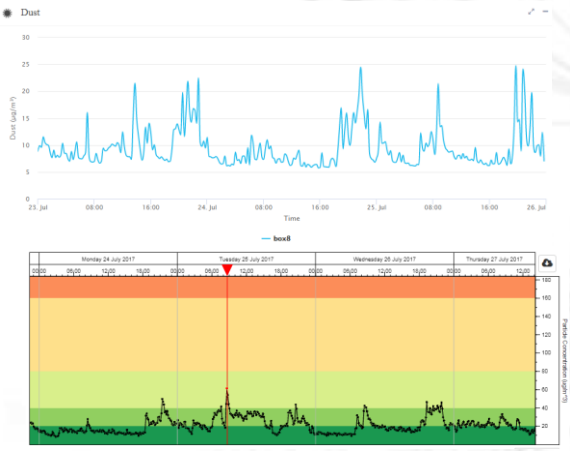
Difficulty connecting sensors to the network or recovering data…

On-Site measurements

Sensors installed in a house, in the countryside

- Range of measured indoor particulate matter during 1month





→ **Disparity of values (Min – Max)**

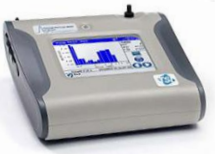
Tests at CETIAT

Testing room – 8 m³

- External supply fan + high efficiency filter
- Injection of pollutant + indoor comfort fan
- Sensors in central zone

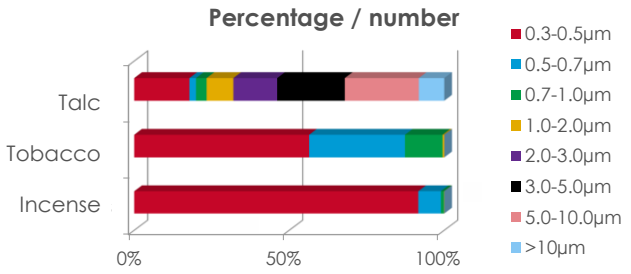
Reference measurement/particles:

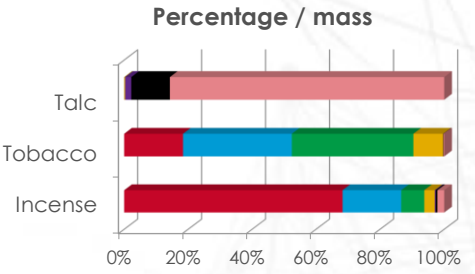
- Counter of Particules (COP) TSI 3330
- 7 channels 0,3 to 10 µm
- Transition from number to µg/m³ by calculation + hypothesis on particles density (2.8)



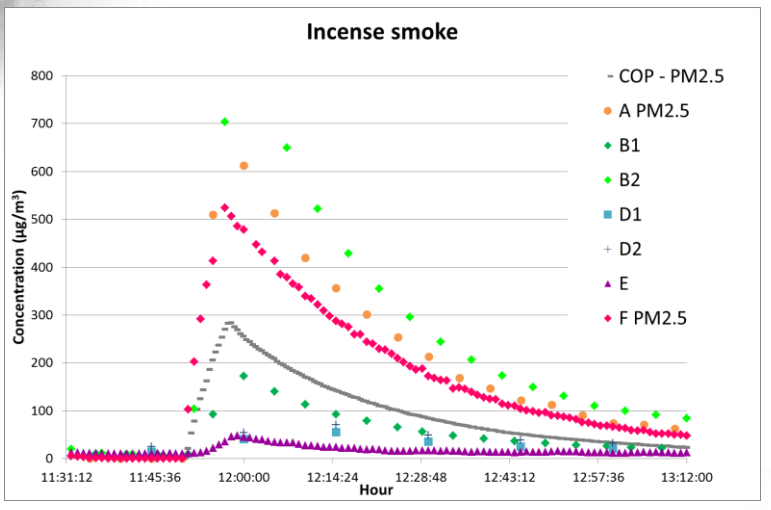
Particles generated

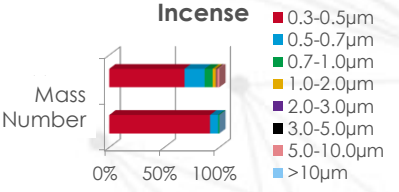
Talcum powder, tobacco smoke and incense smoke were injected in the test room





Sensor response to incense smoke



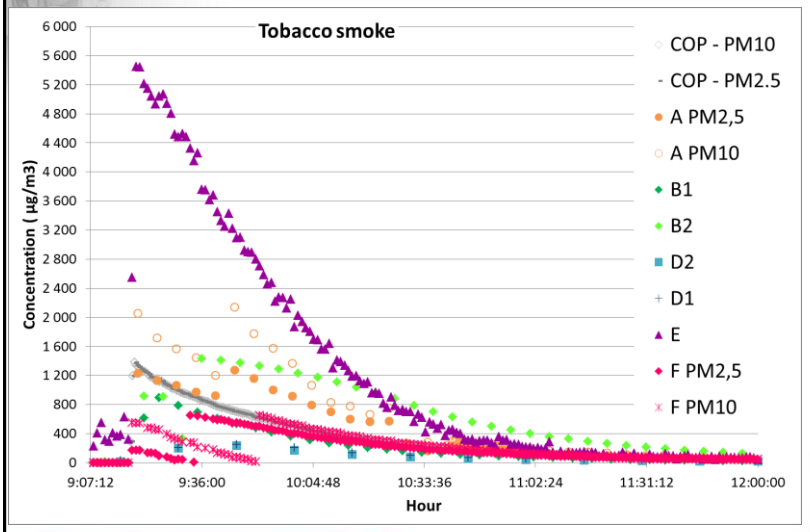


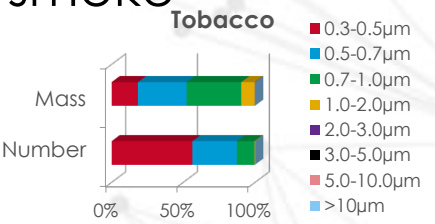
Incense moke is mainly composed of very small particles

$B_2 > A > F > B_1 > D_{1\text{-}2} > E$

→ **Differences due to:**
- **Sampling**
- **Average values**
- **Sensitivity**

Sensor response to tobacco smoke



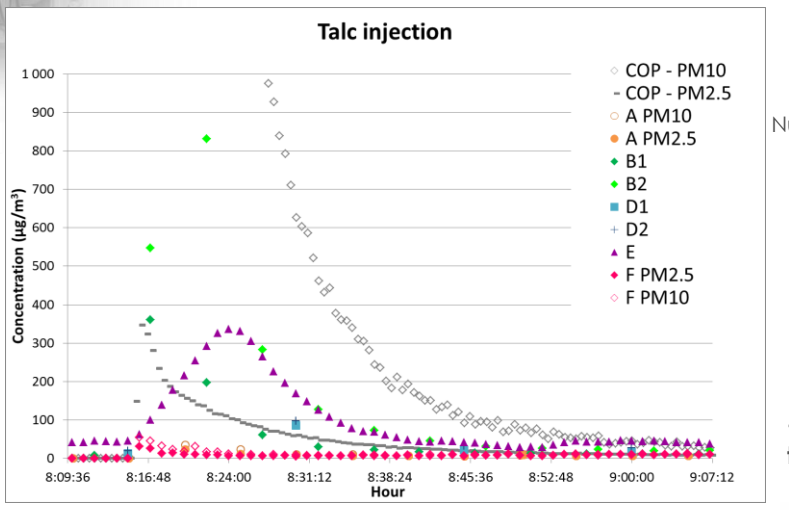


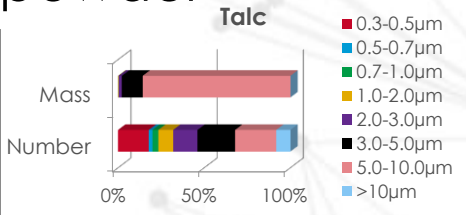
Tobacco smoke is mainly composed of fine particles

$E > A_{PM10} > B_2 > A_{PM2,5} > F > B_2 > D_{1-2}$

→ the orders of magnitude of the responses differ with another particle composition

Sensor response to talcum powder



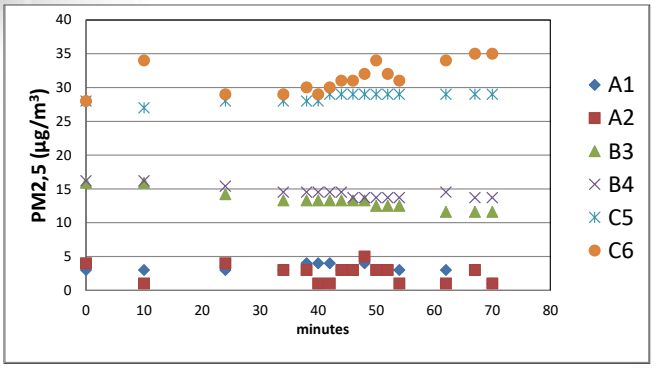


Talcum powder is heavier and deposits more quickly

$B_1 > B_2 > E > D_{1-2} > A > F$

→ Some sensors react very little to talcum dispersion

Measurement at low level of particles



Indoor concentration of PM2.5
No particle generation

Basic level : ~5 / 15 / 30 µg/m³

Disparity of values even with no particle generation

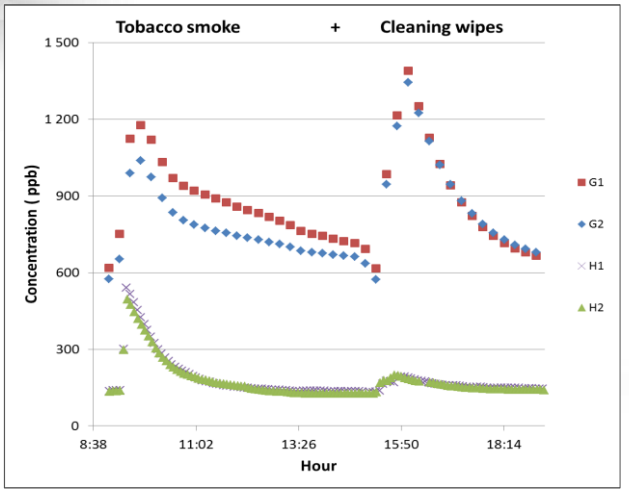
VOCs measurements

Information available on manufacturers' technical specifications for particles measurements

G	H	I
• Sensitivity: hydrogen gas, hydrogen sulfide, ammonia, ethanol, toluene, and formaldehyde • Value in ppb	• Sensitivity: Formaldehyde, iso-butane, toluene, methane, ammoniac, benzene, etc. (*) • Range:100-1000 ppb	• Range : 0-9,9 mg/m³ • Resolution 1mg/m³

→ 2 sensors give ppb values
→ 1 sensor give mg/m³ value (which hypothesis for gas density ?)

Sensor response to VOCs

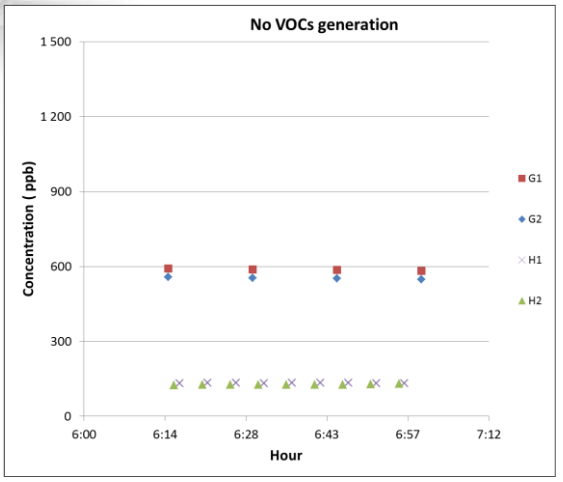


Comparison of two sensors
With two different sources of VOCs

→ **Values differ between sensors G and H**

→ **the order of magnitude of the responses differ Tobacco/cleaning wipes**

Measurement at low level of VOCs



Indoor concentration of VOCs for 2 sensors in the CETIAT testing room

No VOCs generation

Basic level : 130 / 600 ppb

Disparity of values even with no VOCs generation

Conclusions

Measurement results

- High disparity between sensors
- Impact of data sampling and average
  - Time lag
  - Lower peak value
- Impact of the pollutant compositon
  - Sensor responses are different / nature of pollutant
  - Particles: incense, tobacco, talc
  - VOCs : tobacco, incense, cleaning wipes
- Few informations available
  - Sensitivity /selectivity
  - Data processing
  - Ambient conditions influence

Assessment of IAQ Sensors

- Need to characterize the generated pollutant
  - Nature and Composition
  - Properties (density, …)
- Periodic calibration is needed
  - Complex pollutant
    - Not only one gas for VOCs
    - Several Particles generations (fine, very small, ...)
  - On-site ?

Which use of « low-cost » sensors (PM VOCs) ?

For individual use

- OK for information purposes only
- What is the influence of residents activities (cooking, cleaning, …) on some IAQ metrics

Not ready for fine DCV use

- reliability of data and connexion, durability, calibration, …

6 March 2018

Thank you for your attention