European Network on New Sensing Technologies for Air Pollution Control and Environmental Sustainability - *EuNetAir*

COST Action TD1105

WGs and MC Meeting at ISTANBUL, 3-5 December 2014

Action Start date: 01/07/2012 - Action End date: 30/06/2016

Year 3: 1 July 2014 - 30 June 2015 (Ongoing Action)

Outline of (ULg) Chemical Sensors Applications for IAQ Evaluation

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Arlon campus environnement

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ULg / Belgium

COST is supported by the EU Framework Programme

ESF provides the COST Office through a European Commission contract

A better IAQ?

"2 000 000 Healthy Life Years (3%) are lost every year due to indoor air Exposure in EU"

Two approaches

1. Source reduction

Upstream: i.e. building materials with low emissions → CE mark

Downstream: i.e. green ambulance

2. Ventilation improvement

Energetic and CO_2 , RH considerations: recommended ventilation rate 4 L/s per person

15m³/h.pers (0.6 h^{-1}) * **COEFFICIENT RELATED TO IAQ**

(source: HealthVent project)

Evaluation with sensors ?

Devices already commercialised

electrochemical cells, NDIR, PID, "MOS"

for CO_2, TCOV, HCOH, O_3, NH_3, H_2S, NO, NO_2, SO_2, PM

Outline of sensors applications

Continuous and real time monitoring

- control systems:

  ventilation systems + dirty, moulds indicators
  air treatment equipments
  intelligent materials (active paints)

- air quality indicator for

  Regulations: i.e. French decree on thresholds levels for HCOH, Benzene in public buildings (2013)
  Building Environmental efficiency: BREEAM, LEED, HQE

HQE: NO_2 CO Benzene TVOC PM 2.5 PM 10 Radon Formaldehyde

Punctual and real time monitoring (handheld devices)

- source identification
- fast diagnosis

"Lab" analysis

- assessment of emissions from building materials
  →labelling

CCE EURO *Regulation (EU) No 305/2011 laying down harmonised conditions for the marketing of construction products (89/106/EEC); standards EN 16516 and 16402 (2013)*

Mould detection

Most frequent problems in buildings

SBS
respiratory infection
asthma
skin and eye irritation
headache
cough
nausea

➢ Usual Evaluation:

quantity of viable spores (air, surface and building material, settled dust)
results obtained after several days

✓ New methods: detection of fungal components, mycotoxins

microbial volatile organic compounds (MVOCs)

Advantages:

these compounds can penetrate barriers not penetrable by spores
→facilitating the detection of hidden moulds

Mould detection

Chemical sensors for source identification
with respect to a MVOC pattern???

- ❑ Selectivity? → sensor array (« e-nose » principle)
- ❑ LOD?

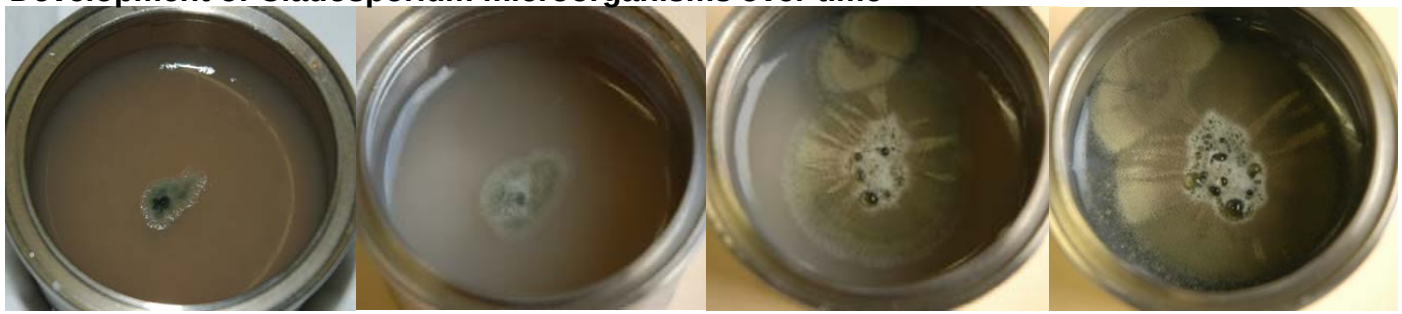
- ➢ VOC for moulds (MVOC): typical of moulds contamination?
- ➢ MVOC pattern specific for specific moulds?
- ➢ No confusion with VOC indoor air background?
- ➢ Concentration level – is it detectable?

Mould detection

- MVOC: typical of moulds + pattern specific of moulds? *(Source: HEMICPD Belgian project)*

  study of VOC produced under defined lab conditions
  learning whether field measurements can identify MVOCs

Development of Cladosporium microorganisms over time



agar culture medium

- Cladosporium cladosporoides
- Aspergillus versicolor
- Penicillium purpurogenum
- Stachybotrys chartarum

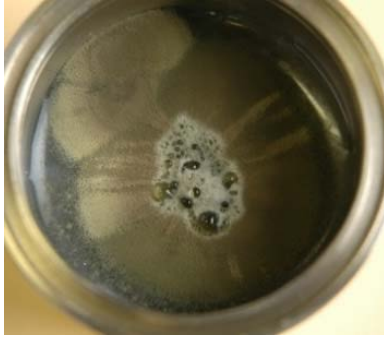
Tenax TA cartridges on the output of the µ-CTE under the following conditions:

- o Temperature: 23 °C ± 2 °C
- o Relative humidity: 0 % ± 5 %
- o Sampling flow: 100 mL/min
- o Sampling duration: 30 minutes
- o Sampled volume: 3,0 L

TD-GC-MS (series iso 16000)
Reference (substraction)

Lor, M., Vause, K., Dinne, K., Goelen, E., Maes, F., Romain, A.-C., Nicolas, J., Degrave, C., Horizontal evaluation method for the implementation of the Construction Products Directive – emissions from construction products into indoor air, Healthy Buildings Syracuse, NY USA, 2009.

Mould detection



Results for moulds alone

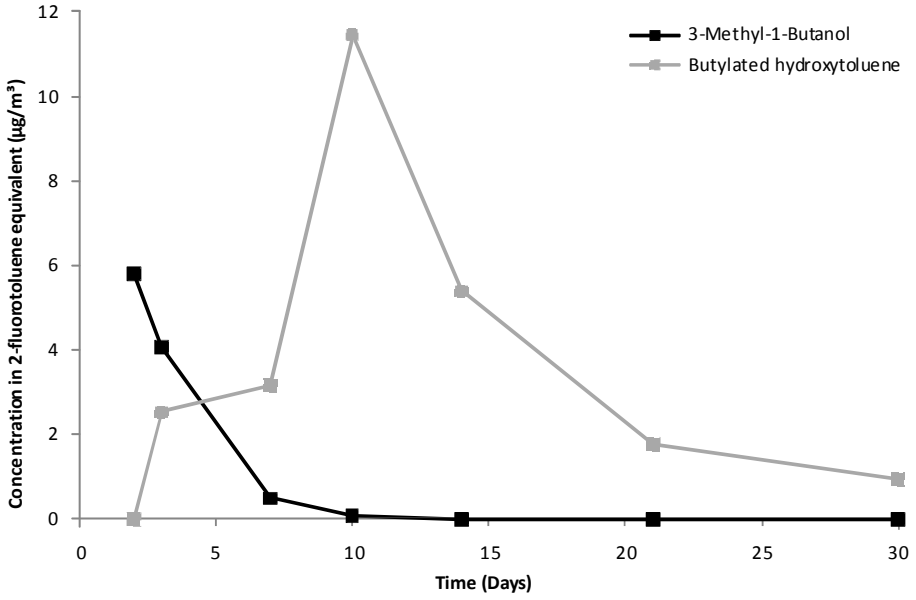


Figure 11 : Evolution of the principal MVOCs emitted by a strain of Cladosporium (strain 01)

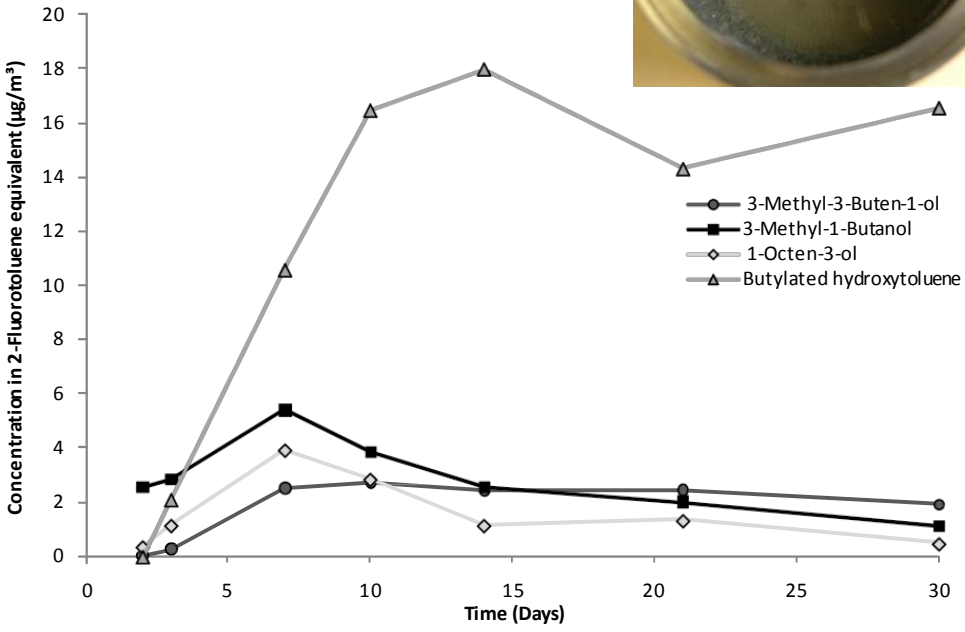


Figure 18 : Evolution of the principal MVOCs emitted by a strain of Penicillium

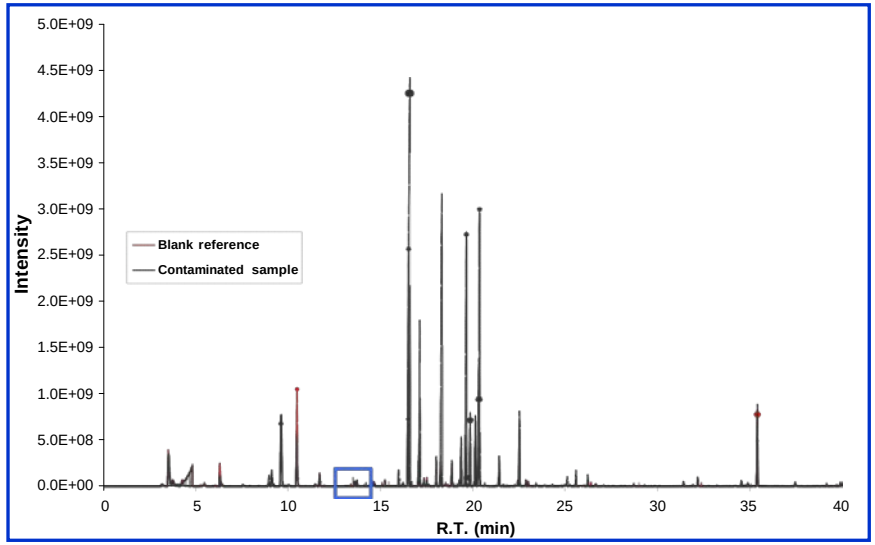
- Complex emissions (several compounds)
- Two MVOCs always present and helped to highlight fungial activity:
  3-methyl-1-butanol and butylated hydroxytoluene
  chemical markers

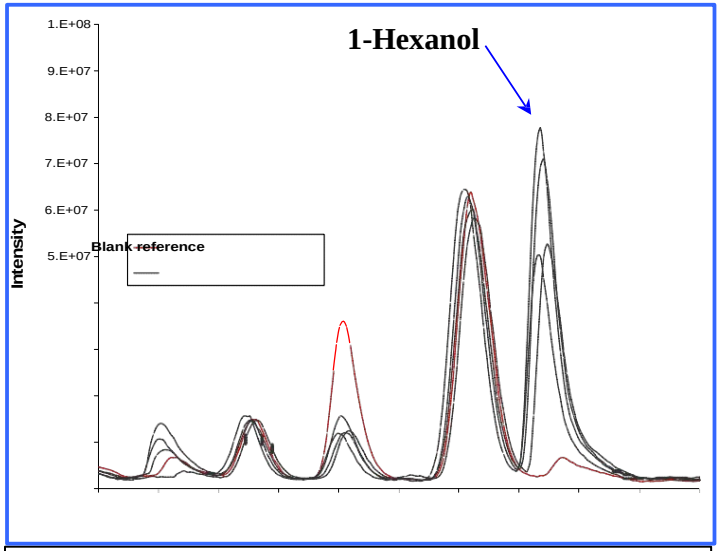
Source: HEMICPD Belgian project

Mould detection

Results for moulds on building materials

i.e. **OSB** (inoculation of Penicillium on 9 OSB samples)





high VOC background:
mainly terpenes
when contamination:
↓aldehydes and ↑ketones and alcohols

1-hexanol present in all contaminated samples
not in the emission profiles from the blank reference

Wallpaper
low VOC background
when contamination:
↓aldehydes and ↑alcohols

✓ VOC for moulds (MVOC) typical of moulds contamination?
✓ MVOC pattern specific for specific moulds?
No confusion with VOC indoor air background?
Concentration level detectable?

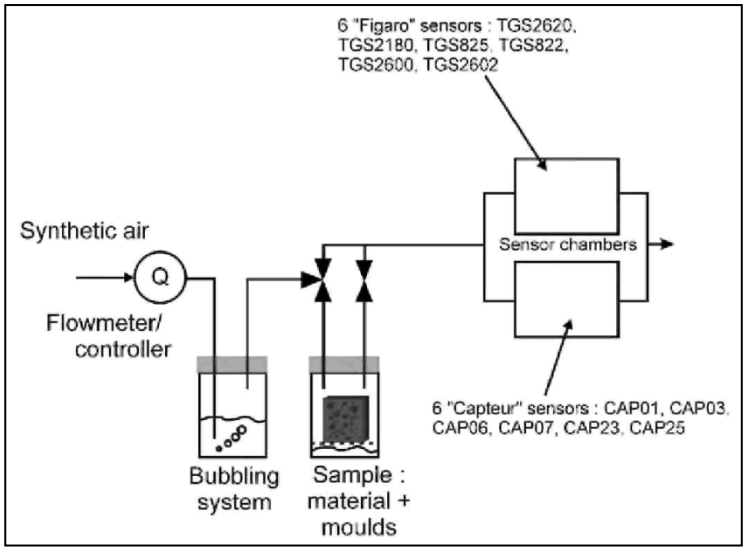
Source: HEMICPD Belgian project

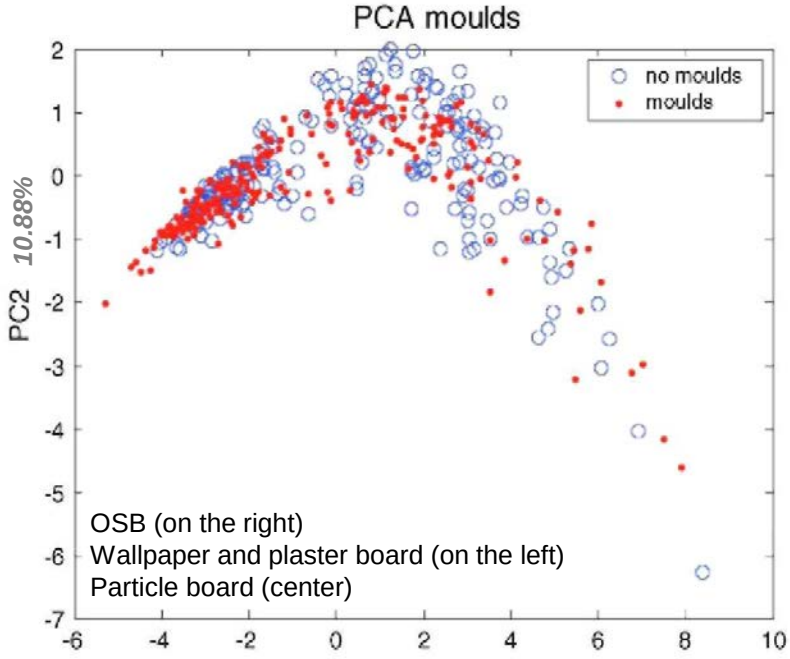
Mould detection

Sensor tests*

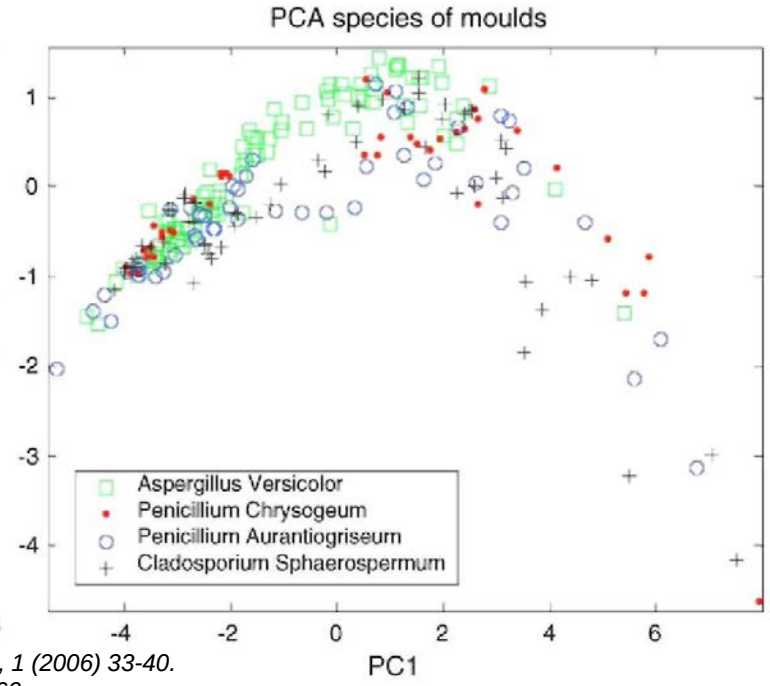
Duration: 4 months
Sampling: randomly
First set: 1 month for data processing algorithm development
Second set: last month (4) for classifier testing (posterior classification
New experience: 4 months later (dration 3 months)

Materials	Samples	Type of mould							
		A. versicolor		*P. chrysogenum*		*C. sphaerospermum*		*P. aurantiogriseum*	
		First set	Second set	First set	Second set	First set	Second set	First set	Second set
Oriented strain board	Clean	27	16	21	22	15	20	15	26
	Contaminated	27	16	11	18	16	16	12	12
Plasterboard	Clean	27	16	21	22	18	22	15	27
	Contaminated	27	16	11	18	16	17	15	11
Particleboard	Clean								
	Contaminated								
Wallpaper	Clean								
	Contaminated								
Total	Clean								
	Contaminated								





OSB (on the right)
Wallpaper and plaster board (on the left)
Particle board (center)



** Kuske, M., Padilla, M., Romain, A. C., Nicolas, J., Rubio, R., Marco, S., Sensors and Actuators B: Chemical, 119, 1 (2006) 33-40.*
Kuske, M., Rubio, R., Romain, A. C., Nicolas, J., Marco, S. Sensors and Actuators B: Chemical, 106, 1 (2005) 52-60.
Kuske, M., Romain, A.-C., Nicolas, J., Building and Environment, 40, 6 (2005) 824-831.
Kuske, M., Rubio, R., Nicolas, J., Marco, S., Romain, A. C., Prooceedings of ISOEN'03, Riga, Latvia, June 25-28, 2003, 2003

Mould detection

✓ VOC for moulds (MVOC) typical of moulds contamination?

YES

✓ MVOC pattern specific for specific moulds?

YES AND MARKERS COMPOUNDS

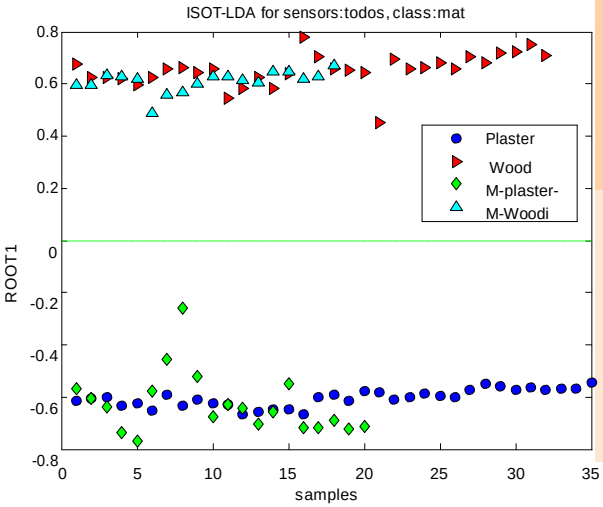
No confusion with VOC indoor air background?

INTERFERENCES

MVOC PATTERNS RELATED TO SUBSTRATE (MATERIALS), ENVIRONMENTAL CONDITIONS, SPECIES

Concentration level : is it detectable?

< 10µg/m³ per MVOC…



Chemical sensors for source identification with regards to a MVOC pattern???

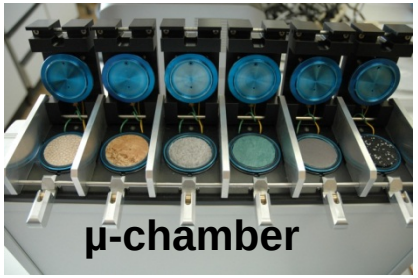
- ❑ Selectivity? →sensors array (« e-nose » principle): YES
- ❑ LOD? TOO HIGH

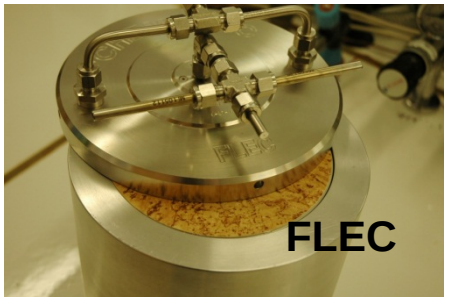
- **Materials more separable than the contaminated-non contaminated**
- **Important background**
- **We had not identified specific moulds**
- **Sensor sensitivity to humidity**
- **CO_2 effect?**

Building material emissions

HEMICPD project (2007-2010)

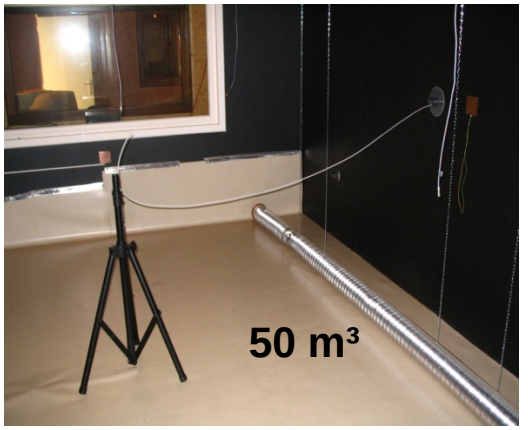
Horizontal evaluation method for the implementation of the Construction Products Directive"-Emissions to indoor air concerned the marking of building materials





ULg tasks

- VOC TD-GC-MS - in a big chamber
- Odour-Emission relationships
- Test of the sensors array principle to monitor the compounds emanating from different building materials during 28 days, in emission test chambers



Romain, A.-C., Degrave, C., Nicolas, J., Lor, M., Vause, K., Dinne, K., Maes, F., Goelen, E., Olfactory, chemical and e-nose measurements to characterize odors emission of construct materials for the implementation of the European construction products directive (CPD) on a Belgian level, OLFACTION AND ELECTRONIC NOSE: Proceedings of the 13th International Symposium on Olfaction and Electronic Nose, Brescia (Italy), 2009

Lor, M., Vause, K., Goelen, E., Maes, F., Romain, A.-C., Nicolas, J., Implementation of health aspects (ER N°3) in the Construction Products Directive (CPD) regarding emissions to indoor air, 11th International Conference on IAQ and Climate Denmark 17th-22nd August 2008

Building material emissions

Air sampling and analysis

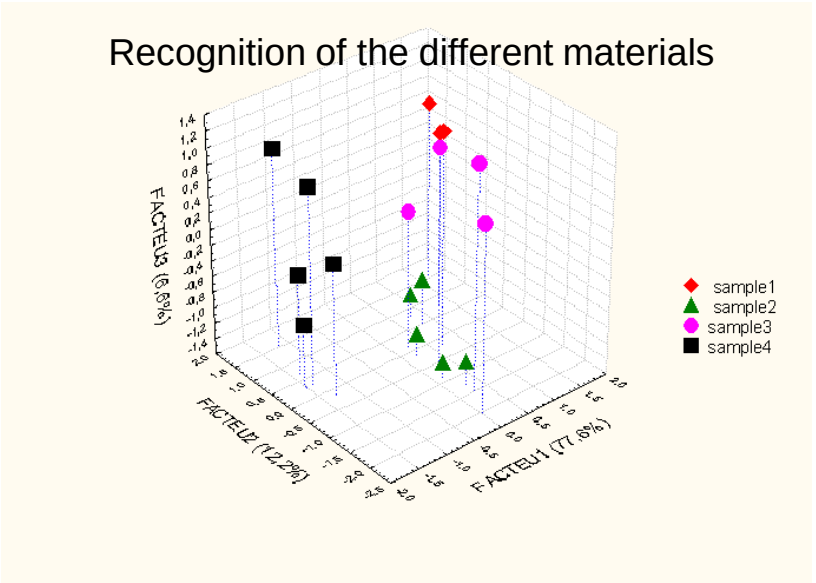
1. Pumping air at 60 litres into a Tedlar bag (closed door)
2. Sampling the collected air in Tenax cartridge
3. Analyzing the sample air by TD-GCMS

Building material emissions

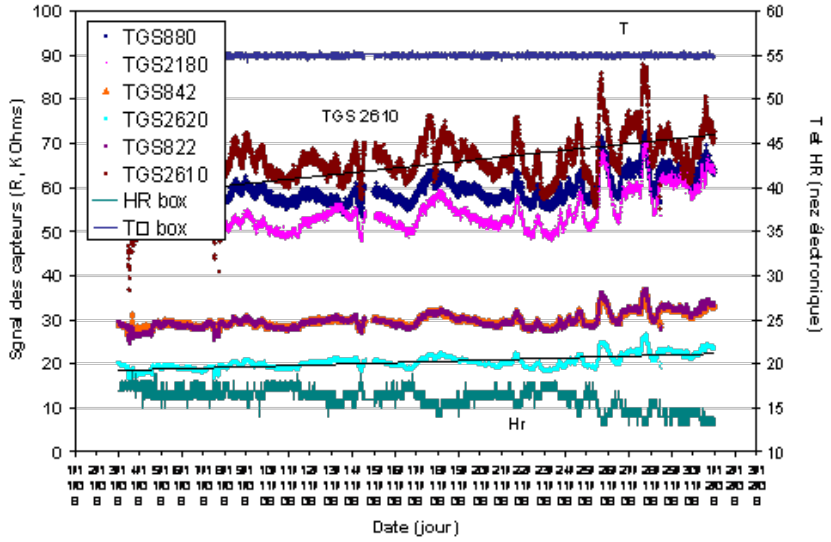
6 Floor coverings were tested:

2 PVC floor coverings
2 linoleum floors
1 carpet
1 versatile rubber flooring

Recognition of the different materials



Continuous material emissions monitoring during 28 days



« Abatement » products

3 industrial projects (2010-2012)

wallpapers with active reagent

to either oxidise (Titane oxide+uv) or capture VOC (molecular chelating agents)

Detection of odour-non odour with the chemical sensors (MOS)?

Test of sensor array **in real conditions**:

- chip shop (100-800 uo_E/m^3 with a max 3000 above the fryer)
- company toilet (100-600 uo_E/m^3)
- garbage room (200 and 500 uo_E/m^3)

+ GC-MS analyses

+ olfactometry measurements

Results

- ☑ Identification of odour and non odour ambiance
- ✖ Not always able to correlate “odour”-”compounds concentration”
- ✖ Not able to discriminate the different odours
- ✖ Odour concentration has to be > 100 uo_E/m^3

cost
EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

« Abatement » products

Efficiency of the product pulverised on the walls?

Test of the sensor array **in real conditions**:

- French fries shop (100-800 uo_E/m^3)
- Garbage room (200 uo_E/m^3 and 500 uo_E/m^3)

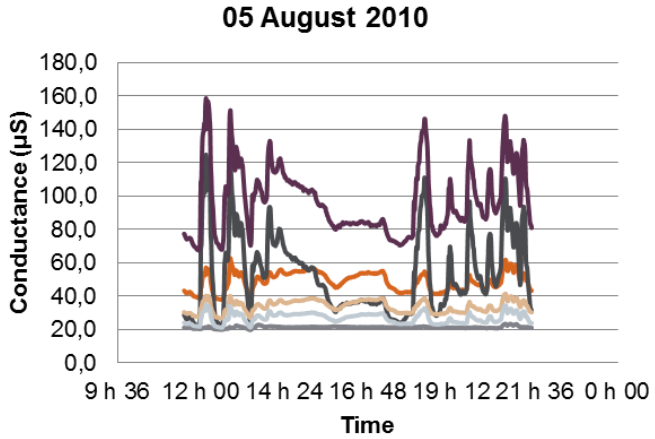
+ GC-MS analyses
+ olfactometry measurements

Results with «pulverised » walls:

In the French fries shop: odour reduction (around 35%)
VOC reductions (around 30%)

✖ Lab-built « e-noses »: no proofs of a significant reduction of « odours » during the day

✓ But-faster reduction of odour between days (fryers ON) and nights (fryers OFF)



✓ Garbage room:

Classes	Odourless	Odorous
Non pulverised observations	25%	**75%**
Pulverised observations	41%	**59%**

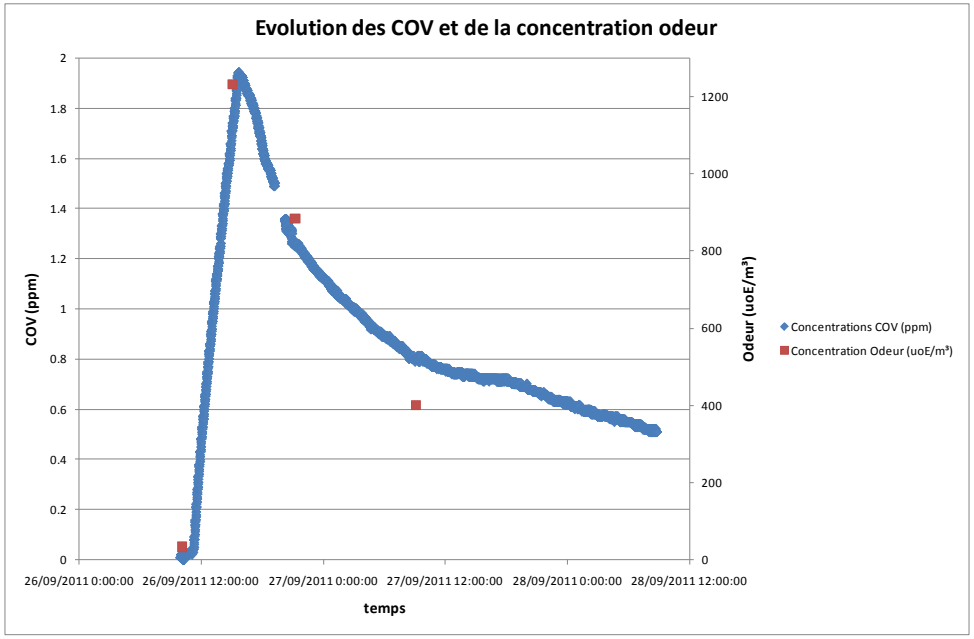
« Abatement » products

Methodology development

Tests **in emission chamber** (50m³):
fryer in the middle of the chamber

PID (VOC)
Olfactometry (concentration + intensity)

Results with «pulverised » walls :



date	time	Fryer state	Odour concentration (uo_E/m^3)	VOC (PID) (ppb)
26/09/2011	10 h 10	Fryer OFF	33	10
26/09/2011	15 h 03	**Fryer On at 11h00** and OFF at 15h40	1.232	1720
26/09/2011	21 h 15	06 hours after switc off	883	1250
27/09/2011	9 h 08	18 after swich off	401	800

Mainly: 1-Penten-3-ol, Octane, 2-Heptenal, (Z)-, 2,4-Heptadienal, (E,E)-, Nonanal, 2-Decenal, (E)- et 2,4-Decadienal, (E,E)-

« Abatement » products

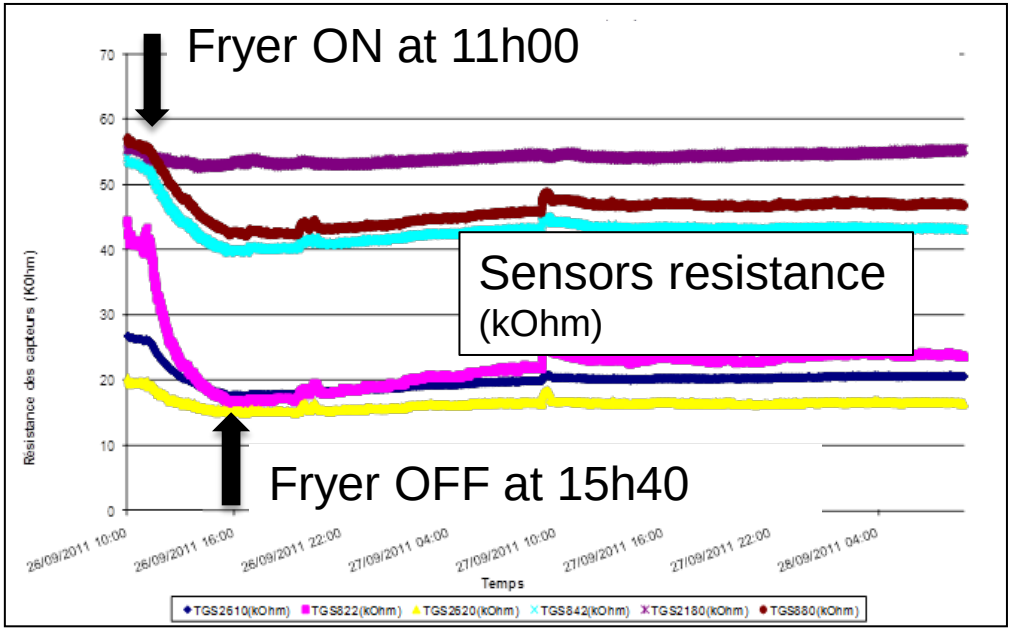
Efficiency of the product pulverised on the walls

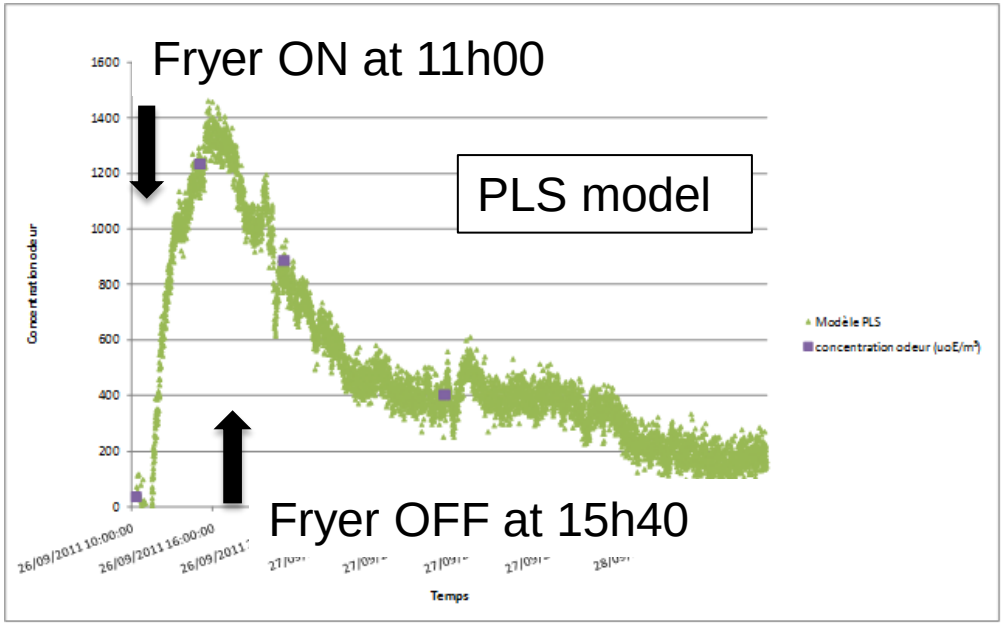
Tests in emission chamber (50m³):
fryer in the middle of the chamber

MOS sensor array
PID (VOC)
Olfactometry (concentration + intensity)

Panellings were pulverised outside the chamber and installed in the early morning before the tests

Results with «pulverised » walls:





« Abatement » products

Efficiency of the product pulverised on the walls

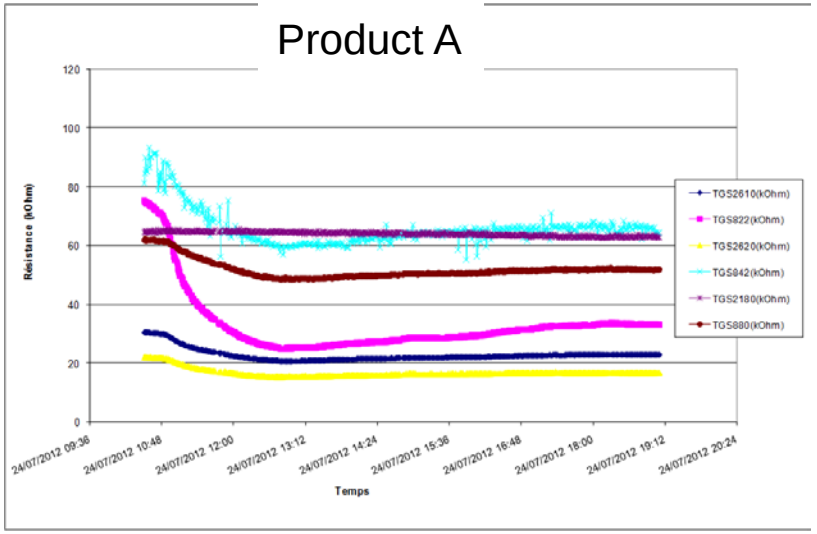
Tests in emission chamber (50m³) **during 5 continuous days** (july 2012)
fryer in the middle of the chamber

Day 1 : without product
Day 2 : with product A
Day 3 : with product B
Day 4 : with product C
Day 5 : without product

Panellings were pulverised outside the chamber and installed in the early morning before the tests

Results:

Product A: faster decrease of the odour (one night is needed) than without the product, but low recovery of the sensors
Product B: significant odour decrease after 06h
Product C: also reduction for high odour level



Take home message

- Push for development of new sensing technologies related to the IAQ evaluation
  - arrival of European and National laws,
  - emergence of the Environmental Assessments of buildings (Breeam, HQE,…),
  - increased awareness of the impact of indoor air quality on health

- Various interesting applications for chemical sensors and different Stakeholders' requirements

- Previous ULg studies highlighted several MOS limitations
  - high LOD
  - Lack of selectivity
  - Interferences
  - Low recovery time
  - (drift, humidity, …)

WAIT and SEE

- Emergence of new sensing materials and new measurement principles (IMS)

Perspectives are again opened!

We plan to pursue again these previous projects

Chemical Sensor technologies in the world of IAQ

✓ What we need

- **Low cost sensors**
  to install several devices in the same room
- **Long life time**
  to avoid costly development of classification and quantification models
- **Low drift and robustness**
  resistant to harsh environmental conditions
- **Lower LOD** (or preconcentration devices)
- **Selectivity** (sensor array, T Modulation) ; cross-sensitivities
- **Low interferences**
- **Low humidity effects** (T is not as important)

What we don't need

- Accurate output of chemical concentration:
  alarm, presence-absence are often adequate

- Battery is not always required

Acknowledgments

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  - **VITO: Eddy Goelen, Frederick Maes**
  - **CSTC: Marc Lor (VITO), Karla Dinne, Kevin Vause**

And my team SAM:

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Noémie MOLITOR
Laurent COLLARD
Catherine HEYMAN




isoen

International Symposium on Olfaction and Electronic Nose

28 June - 1 July 2015

Dijon France

https://colloque.inra.fr/isoen2015

Mobile gas sensing
Analytical techniques
Bio-inspired sensing
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Computational models
Automotive
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Consumer
Odor generation
Software
E-Nose
Correlations with references
Olfaction
Other gas detection
Sampling techniques
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Solid State Sensor Technologies
Food
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Ion Selective Electrodes
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Instrumentation design
Biological Principles of Olfaction
Breath
Dijon
Gas sensors testing
Odor Intensity Measurement

About ISOEN conferences

isoen
International Symposium on Olfaction and Electronic Nose

International Symposium on Olfaction and Electronic Noses

- ran by the International Society for Olfaction and Chemical Sensors
  - ✓15th issue, since 1994
  - ✓Scientific Committee since 1999
  - ✓Wolfgang Göpel Memorial Award
- ISOCS society
  - ✓Executive Board
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Topics

- **Solid State Sensor Technologies**
  - **Gas sensors**
  - **✓Biosensors**
  - **✓Ion Selective Electrodes**
  - **✓Other gas detection technologies**
- **System level**
  - **✓Gas Sensor Testing Systems**
  - **✓Sampling Techniques**
  - **✓Instrumentation Software/Hardware design**
  - **✓Data Processing**
- **Odor / aroma generation**
  - **✓Olfactometers**
  - **✓Olfactory displays & shooters**

Topics

- **Olfaction**
  - ✓Biological Principles of Olfaction
  - ✓Odor Intensity Measurement, cross modalities
  - ✓Bio-inspired sensing
  - ✓Computational models of the olfaction and Bio-inspired Algorithms
- **Analytical techniques**
  - ✓Correlations with references, Experimental Design, Process Control, Calibration, Transfer
- **Applications**
  - ✓Industrial, Environment, Automotive, Breath, Medical, Consumer,…
  - ✓Mobile robots based on gas sensing

Thanks for your attention

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